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FRICTIONAL IGNITION OF GAS BY MINING MACHINES

BY IRVING HARTMANN

United States Department of the Interior — September 1955

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UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
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J. J. Forbes, Director

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INTRODUCTION

Several recent ignitions of firedamp - a mixture of methane and air - in American coal mines have been attributed to frictional heating when hard rocks were struck while cutting and drilling coal seams. Although none of these ignitions caused severe explosions, they call attention to a problem that can become increasingly significant as mechanized mining is developed further. The power in and rapid release of energy from high-speed machinery has increased the rates of advance into virgin coal creating many problems. Unforeseen faults and hard mineral inclusions may be encountered; coal brought down in this way is finer in size; more gas is released from the seam; it is frequently more difficult to provide adequate ventilation at the face; and new roof-support problems must be solved. In particular, continuous mining machines (also known as continuous miners) greatly increase the frequency of contact between cutter bits and minerals. In view of these conditions, it may be expected that more gas ignitions will occur as a result of frictional heating unless the situation is understood and remedial measures are introduced.

The problem of frictional heating is not new in coal mining. In Europe, particularly in England, it has been a concern for more than a century. During the last 15 to 20 years frictional ignitions have been a major cuase of explosions in British mines. Explanations for the greater number of such ignitions in England may be the special character of the coal measure strata, the mining methods, the rate of gas emission and possibly its composition, and less effective ventilation near the face. To reduce the ignition hazard, considerable laboratory and field research has been conducted, particularly by the Safety in Mines Research Establishment, Ministry of Fuel and Power of Great Britain. Much of the information presented in this report has been drawn from these studies.

The purpose of this paper is to call the attention of mine operators to potential ignition hazards associated with the use of mining machines; correct certain misimpressions regarding the relative effects of various metals in cutting bits and other equipment; review several ignitions and explosions caused by friction; summarize findings of research on the subject; outline the possible mechanisms of ignitions; and discuss preventive measures against explosions. Although the report is concerned primarily with ignitions by mining machines, some consideration is given to related ignitions by friction and impact between rocks, by contact of metals with rocks or with other metals while setting and withdrawing roof supports,

etc. Ignition by friction in industrial plants, where the problem long has been recognized, is discussed briefly.

Although considerable basic knowledge has been obtained on the origin and cause of frictional ignitions and various preventive measures have been developed, much is still unknown and the present safeguards are not perfect. Research now in progress should contribute valuable information on ignition by friction in gassy mines and means of prevention.

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NATURE OF FRICTIONAL HEATING AND IGNITION

Heat is produced whenever energy is utilized to perform work or when one form of energy is converted to another form, for example, when electrical energy is converted to mechanical energy in electric motors. In general much heat is evolved by the friction and impact of objects. The release of heat under most conditions raises the temperature of adjoining objects and the surrounding atmosphere. When the amount and rate of heat production is high and occurs within a small space, the temperature increase may be considerable. Friction and impact can cause heating of one or both contacting surfaces to a faint or even an intense glow, smoldering, smoke, sparks, flashes, flame, and what appear to be electrical discharges. In the presence of combustible vapors, gases or dusts, the heat produced by friction may be a potent source of ignition.

In mining coal, large forces are applied and much energy is expended. Many machines depend on friction for their effectiveness, and various materials, including rocks and metals, come into frictional and impact contact, frequently in the presence of an explosive atmosphere. Accordingly, the problem of heating and the possibility of ignitions must be considered in the design, construction, and use of mining machines. To produce an ignition the amount of mechanical energy converted to heat need not be large, but heat must be liberated rapidly and within a small volume. The nature of the contacting surfaces, the type of contact, and the composition and ignition temperature of the combustible atmosphere are also important factors, which will be discussed later in some detail.

In general, flammable mixtures of gas are ignited by frictional heating in two ways: (1) A small volume of gas is heated to the ignition temperature by direct contact with a hot part of one of the rubbing surfaces; (2) small heated particles, commonly termed frictional sparks, are projected into the gas mixture. These frictional sparks are small, hot particles of solid matter torn from one of the larger pieces in contact. The particles may be inert, in which case their temperature is limited by their melting point, or they may be chemically active, in which case their temperature is augmented by oxidation. The existence of frictional sparks should be considered as a warning in coal mines where a flammable atmosphere exists, but they do not necessarily mean that an ignition or explosion will occur. To ignite the gas, the sparks must have a high temperature and their heat content must be sufficient to impart the necessary amount of heat to a small volume of the

gas mixture. The ability of sparks to ignite firedamp is greatly restricted by the short period of contact with the gas, owing to cooling by convection, and to the "ignition lag" period of the gas, which varies with composition and with temperature. All these factors make flying sparks generally less dangerous than sparks whose paths are obstructed by a thermal insulator at an early stage.

FRICTIONAL IGNITIONS IN INDUSTRY

The sensitivity of many gases, vapors, dusts, pyrotechnic mixtures, explosives, and other compounds to ignition by hot surfaces and by sparks produced by friction and impact is very important in many industries. Many fires and explosions have been attributed to these causes and considerable attention has been given to alleviating the hazard. Excessive heat or sparks can be produced by neglected or worn bearings of rotating machines; during grinding, machining, buffing, and other finishing of metal objects; during repair and construction work; in using various hand tools; by friction or breaking of fan blades; through entry of tramp iron into pulverizing mills; by picks, shovels, and similar implements striking concrete floors; by friction of slipping machine belts; and in many other ways. In industry the majority of frictional ignitions are caused by metal-to-metal contacts, whereas in coal mines such accidents have been due primarily to metal-rock friction, as with cutting machines. Ignitions and explosions have been observed as a result of frictional heating in plants producing gasoline, naphtha, and other vapors; primary explosives; sulfur, plastics, grain, flour, and many other dusts.

Industrial safeguards against frictional ignition include proper maintenance of machines to avoid overheated bearings; segregation of spark-producing operations from other plant areas; adequate ventilation and suitable dust-collecting systems; magnetic separators to prevent entry of ferrous metal into machines; substitution of inert gas for air in closed equipment; prohibition of shoes with exposed cleats or nails; substitution of spark-resistant tools for ordinary steel tools; etc.

Spark-resistant tools, frequently termed "nonsparking" tools, are used in various industries where explosion hazards exist. Safety codes of the National Fire Protection Association recommend this practice under certain conditions. In Western Germany, iron or steel tools are prohibited in places where volatile substances are stored or where explosive gases, vapors, or dust are present in dangerous quantities. Ideas regarding the effectiveness of spark-resistant tools have undergone considerable change. At one time it was believed that elimination of steel and iron tools would do away with frictional ignition hazards. Later it was found that other materials, including light alloys, especially those containing magnesium, can produce highly incendive sparks by contact with other metals or with concrete. The most commonly used spark-resistant tools are made of various copper alloys, with beryllium-bronze the preferred material. Beryllium alloys are suitable because by proper heat- and solution-treatment they can be hardened and provided with cutting edges and other desired characteristics. It is realized now that even spark-resistant tools can produce incendive sparks under some conditions, for example, if the impact energy is great enough to break or tear off small parts of the metal that is being worked and heat these fragments to a high temperature or induce their rapid oxidation. Various tools for handling hazardous materials are made of wood, leather, and plastics.

The friction of ferrous metals produces much sparking, owing to the ease with which iron oxide is formed in air when iron particles are detached from larger pieces. The particles are first preheated by the energy required to tear them from the parent metal; this is followed by rapid exothermic oxidation, which raises

their temperature to incandescence. The copper used in spark-resistant tools has a much lower heat of combustion than iron. In addition, the heat capacity of copper is higher, resulting in much lower temperatures than with iron and little or no sparking in most instances.

MINING OPERATIONS CAUSING FRICTIONAL IGNITIONS

In many mining operations the heat produced by friction and impact is high enough to ignite firedamp or coal dust under certain conditions. In Great Britain where most firedamp ignitions of this nature have been reported, the great majority occurred while cutting coal seams with machines; this was also an important cause of ignitions in other countries. Other causes of frictional ignitions were drilling in the seam; hand picks used for testing the soundness of roof strata, breaking rocks, and testing and cleaning faults; hand shovels striking roof rocks; sledge hammers and other tools striking rocks; continuous miners cutting hard rock inclusions in coal seams; sliding and impact of rocks on other rocks during roof falls and roof caving; steel chocks and props being forced during withdrawal of roof supports; derailing and wreckage of runaway trips of mine cars; projection of detonator fragments from shot holes during blasting; fan blades rubbing against fan casings; and operation of conveyor belts and belt slippage. Heat and sometimes strong sparks have been observed when rock is projected by pneumatic stowers and while loading mine cars, sliding metal roof props in chutes, and tightening roof bolts.

The surfaces whose friction or impact has resulted in dangerous heating or sparking include rocks against rocks, metals (especially steel) against rocks, steel against steel, light metals against steel. The mine rock most likely to create a hazard is siliceous or quartz-bearing sandstone, with iron pyrite next. A few ignitions have been reported when hard shales and ironstone (a stratified iron ore, generally siderite) were struck by steel.

HISTORY OF GAS IGNITIONS BY FRICTION IN COAL MINES

Great Britain

Observations of streams of sparks, lightning-like flashes, and great noise accompanying friction and impact of sandstone rocks during caving and collapse of roof strata date back to 1886. The first firedamp explosion attributed to frictional heating between rocks was reported at the Maindy pit, Glamorgan, Wales, in 1896. It was caused by a fall of roof, which was composed almost entirely of quartz with small inclusions of iron pyrite. When pieces of the rock were subjected to the friction of one piece rotating at 200 r.p.m., firedamp was readily ignited. Three explosions at the Bellevue mine, Alberta, Canada, during the first decade of this century were attributed to falls of rock consisting of bituminous sandstone of fine, even texture, with about 50 percent quartz and 16 percent carbonaceous matter. This rock was found to ignite firedamp during friction tests.

The possibility of igniting firedamp by contact of steel with rock was considered following a mine explosion at the Wallsend colliery, England, in 1785, which was thought to have been initiated by a Spedding mill -- a device that was used for illumination in mines before the introduction of the flame safety lamp. It consists of a rapidly rotating, thin disk of steel and a piece of flint pressed against the edge, producing a stream of sparks. In tests the device was found to be capable of igniting illuminating gas, but it was never proved that it could ignite firedamp.

Early explosions in English coal mines attributed to frictional heating between metal and rock occurred at the Pentre colliery, Glamorgan, in 1880, when a pick struck hard rock; at Great Fenton colliery in 1883, owing to the same cause; and at Orrel colliery in 1902, when a shovel struck roof rock. In 1914 gas was ignited when a pick hit sandstone during roof brushing. Between 1920 and 1929, three explosions were started by frictional heat while operating coal-cutting machines. Between 1937 and 1952, 100 ignitions of firedamp in British coal mines were attributed to frictional heat while using cutting machines; 17 other ignitions were attributed to frictional heating resulting from drilling, striking rocks with hammers, using picks, and derailed mine cars. During the same period, 104 gas ignitions were caused by shot firing, 241 ignitions by open lights, 79 by electricity, and 82 by smoking. These sources account for 85 percent of all firedamp ignitions and explosions.

One firedamp explosion in 1950 was attributed to sparks produced when a drilling machine with a light alloy casing struck a steel roof support. Since then two other explosions were caused by sparks produced when rusty steel wedges were knocked out of light-alloy roof bars under load.

A very severe explosion owing to friction occurred at the Holditch colliery in 1937 when the picks of a cutting machine struck pyrite and ignited gas. Following an initial fire, 8 explosions occurred over a period of 4 hours, killing 30 people, most of them in the last explosion. The most serious explosion owing to frictional heating occurred at the Easington colliery in 1951, when a cutting machine struck pyritic inclusions in the shale bottom of the seam. The resulting gas ignition initiated an explosion of coal dust killing 81 men atmost instantly.

Germany

Since 1922 less than 10 coal mine explosions in West Germany have been attributed definitely to frictional heating. One firedamp explosion (1922) was started by a spark when a steel gear was struck with a chisel during repairs in a hoisting shaft. A second explosion (1922) was produced by the impact of a large piece of sandstone on a steel roof-support arch. A gas explosion (1923) was initiated when a steel roof support was struck with a tool. A strong gas explosion (1925) was attributed to sparks caused by a loose iron fan blade touching a damaged iron casing; as a result of experiments following this explosion, iron or steel fan wheels were prohibited and were replaced by wheels of a special light-metal alloy. Gas was ignited (1931) when a cutting machine struck pyritic inclusions in a coal seam.

In one mine gas was ignited (1933) while cutting a hard coal seam that contained neither pyrite nor sandstone inclusions. The compressed-air driven machine was greatly overloaded, and it stuck several times while the 360-foot long face was being cut. The setting of the cutter bits differed from the normal setting and produced much fine coal dust, requiring expenditure of much energy. After the accident part of the cutter bar was found about 4 feet from the machine to be broken and the cutter chain was bent; the condition of the bits indicated that they had been subjected to very high temperatures. During subsequent tests it was found that the methane in the cut ranged from 5.6 to 53 percent at various stages of the cutting cycle. It was concluded that the bits had been overheated by considerable friction, resulting in the ignition of fine coal dust, which in turn ignited the gas.

In 1953 gas was ignited when a pick struck a piece of rock in the coal bed. In January 1955 gas was ignited when a light metal mine-roof support was struck with a hammer.

United States

In coal mines in this country frictional sparking, and ignitions of small volumes of gas have been observed on numerous occasions while cutting and drilling seams, while tightening roof bolts, and during other mining operations. These ignitions generally have not been considered important enough to form the subject of published reports. During the past 2 years the Bureau of Mines investigated 7 ignitions of this character. A brief account of these incidents follows.

In April 1953 at one mine 2 men were burned, when the cutting bits of a continuous miner contacted the sandstone roof, igniting methane from a feeder in the face of a crosscut. This machine applies a slow boring action to the coal face through two horizontal rows of rotating arms, which are staggered to cut intersecting circles in vertical planes, operating in a manner similar to a group of large core drills. When the machine first attacks a coal face the air can be made to circulate around the bits; however, as the machine head advances into the coal it occupies nearly the entire cross section of the bore, so that air flow is obstructed. About an hour before the ignition, the machine had advanced approximately 90 feet into the dead-end face of the entry. On examining the place an estimated 1.5 percent gas was found near the face. The machine was moved back 35 feet to drive a crosscut to an adjoining worked-out room after the gas had been removed. The crosscut was begun after a deflecting curtain was erected to within 3 to 4 feet of the rib immediately inby the machine to carry air to the machine. The crosscut was 9-1/2 feet wide -- the width of the machine -- and had been driven to a depth of 20 feet when the machine was stopped to permit change of shuttle cars. Normally this takes 3 to 5 minutes, and a test for gas is made during this time. However, on this occasion no test was made. Soon after the cutter head was started again gas was ignited. Ventilation in the cut was not adequate.

In January 1954 gas was ignited by a shortwall cutting machine when the bits struck hard sandstone in an undercut. The machine had just completed a cut 12 feet wide and 8 feet deep when it was stopped to make a test for gas. No gas was detected and cutting had been resumed when the ignition occurred. No one was injured, and the flame was quickly extinguished with rock dust. Ventilation was normal, with about 4,000 cubic feet per minute of air passing the face.

In May 1954, 2 gas explosions were initiated at a mine 2 days apart when bits of continuous mining machines encountered pyritic inclusions in the band of rock immediately above the coal bed. The machines were similar to the one mentioned previously. Four men were burned in the first explosion and one man in the second. The practice in this mine was to advance the machine about 25 feet into solid coal, then to pull back and widen the entry to desired size. The coal seam is gassy, and the manner in which the machine was designed and used, coupled with faulty installation of the brattice cloth, prevented adequate ventilation of the cut. Water sprays were being employed in this machine to allay the dust. Following these explosions a study was made to determine what changes in mining practice are advisable to prevent similar ignitions. It was recommended that advance of the machine into the solid should not exceed 8 feet, unless ventilation at the immediate face can be greatly improved. Further it was recommended that the end of the line brattice be kept close to the face; that doors, check curtains, and other ventilation facilities should be properly installed and maintained; and that mining operations be discontinued and power cut off from face equipment when the methane content of the air near the machine exceeds 1 percent. Several of these measures were adopted, and during the past year no further ignitions occurred at the mine. The Bureau investigator also suggested that with continuous mining machines,

normal mine ventilation should not be depended upon solely. Auxiliary mechanical means should be provided to supply an ample volume of air discharged at high velocity from one or more openings through the head of the machine against the face.

In July 1954 gas was ignited while completing a shear cut when the chain bits of the machine encountered pyritic lenses in the floor; the inby end of the shear cut was found to have penetrated about 8 inches into the bottom. Gas was thought to have entered the cut from a fault that was uncovered after the coal was removed. Cutting into the fault had been expected and gas in abnormal quantities was encountered in the adjoining entries while driving into the fault zone. However, no tests for gas were made before starting the shear cut in question.

In January 1955 an ignition of gas occurred shortly after beginning to drill a hole in drawslate above the coal seam at a place where a shelter hole was to be prepared. The ignition was attributed to friction of the drill bits with the rock. Neither pyrites nor quartz-bearing sandstone were reported in the drawslate. The drill was equipped with a water spray, but it is not certain whether this was in use. Shortly before drilling into the slate, the seam had been undercut and a hole drilled into the coal 8 inches below the drawslate. A test made for gas just before drilling began in the drawslate gave negative results.

In March 1955 gas was ignited while completing a shear cut when the cutting bits of the machine encountered a streak of iron pyrites "or some other hard material" near the floor. Water was being sprayed on the cutter bar to allay dust, and the ventilation at the face was said to be quite adequate at the time of ignition. The report of this incident indicates that the cutting bits had carbide tips. Similarly, the report of the previous ignition while drilling drawslate calls attention to the fact that tungsten carbide bits were used in the high-speed drills. These reports and oral accounts of observed sparking in other mines indicate that hardness of the contacting metal is important. In high-speed machine operations this may be a factor in frictional ignitions, although it is contrary to findings in British and German experiments.

EXPERIMENTAL WORK ON FRICTIONAL IGNITIONS

More than 35 years ago limited experiments were conducted by the Bureau of Mines to determine whether sparks produced when braking locomotive wheels would ignite explosive gas mixtures; no ignitions were obtained in these tests. In another early study on the ignition of gas by heated surfaces, it was found that the ignition temperature of natural gas was reduced by 300° C. when a layer of finely divided iron pyrite was placed on the metal bar being heated in the gas. After many trials it was found that a stream of natural gas could be ignited by directing it on a mass of pyrite dust that had been ignited by a frictional spark. More recently some experiments were conducted by the Bureau on ignition of dust clouds by frictional sparks formed by holding steel against an emery wheel. Dust clouds of aluminum, magnesium, titanium, and sulfur were readily ignited.

In Belgium many tests were conducted in an attempt to ignite firedamp by frictional sparks produced by contact of picks with rock surfaces. The results were negative in all cases. Ignitions were obtained by directing the picks in such a way as to produce glancing blows without sparks but with considerable heat at the points of contact. In other experiments it was found that under some circumstances a fan rotor and a casing made of an aluminum-base alloy produced fine dust that ignited firedamp by contact with a spark from iron.

At the laboratories of the Netherlands State Mines it was found that a quick-release mechanism for roof supports, creating friction between steel and aluminum surfaces, can ignite firedamp. Ignitions could not be obtained when the aluminum was replaced by steel or when there was no rust on the steel friction surfaces. It was also impossible to produce ignitions with friction surfaces made of zinc or a light alloy free of silicon.

Firedamp was ignited in French experiments in 1928 by impact of steel picks against granite under very special conditions. In other experiments in the same year a few ignitions were obtained by sparks formed when steel was pressed against a carborundum wheel.

In 1886 an Austrian investigator succeeded in igniting firedamp by directing it against the point of contact between pieces of rock or iron and a sandstone mill-wheel. With rock against rock ignitions were obtained regularly, but in friction of iron against the sandstone only one ignition occurred.

Germany

In experiments conducted in Germany in 1922 no gas ignitions could be produced by impact of steel drill bits against steel plates. However, glowing particles of iron did produce ignitions if they burned. In 1931, during experiments with a cutting machine in quartz-bearing sandstone, it was found that strong sparks initially failed to ignite firedamp; soon afterward, however, brightly glowing strips appeared in the sandstone in the groove behind the cutting bits. Inspection of the sandstone block after each experiment showed that these grooves were covered with glowing steel particles from the bits, which adhered to the rocks as a result of the high frictional heat. In subsequent cutting these steel particles were heated still more, so that they flamed and ignited firedamp. After the experiments the bits showed considerable wear and scaly deposits. Firedamp was ignited with all types of bits.

Following a strong mine explosion in 1925 it was established that aluminum detonators ignite firedamp easily, as the aluminum is ejected in fine, burning splinters. As a result of this finding, for the first time light metal components were considered as a possible incendiary spark source. Tests in the German experimental mine showed that iron filings blown from a shot hole with permissible explosives produced bright and extensive showers of sparks without igniting firedamp. However, when a few aluminum shavings were added regular ignitions of firedamp occurred.

Since 1947 extensive experiments have been conducted to study the frictional ignition hazard of various steels and light alloys. Some of the resulting conclusions are given: Frictional sparks produced when steel props are compressed or released under pressure as a rule can cause a firedamp explosion under practical conditions; if steel props with aluminum alloy friction plates are used, reactions similar to the thermit reaction may occur under certain conditions and ignite firedamp; components of hard aluminum, containing silicon, may produce dangerous sparks during friction or impact with iron, but use of aluminum alloys with little silicon and considerable copper greatly reduces the ignition hazard; no incendive sparks were produced by friction or impact between aluminum alloys; sparks produced by friction or impact of steel on steel may ignite firedamp, particularly if the steel is covered with rust. In this connection it was found that sparks produced by the impact of rusty iron on aluminum only ignited firedamp immediately at the point of impact, whereas sparks caused by striking steel with rusty iron are

incendive about 10-20 cm. from the point of impact. It is suggested that the danger might be reduced by coating the steel, as with zinc chromate, to prevent immediate contact between steel or rust and the other metal. The possible usefulness of a coating on light metal components is also mentioned.

Great Britain

Systematic research on the causes of frictional ignitions in coal mines was begun in England more than 30 years ago. Much progress has been made, and the work is continuing. Investigations have included fundamental studies on the mechanism of ignition, experimental studies in laboratories, and tests in coal mines to develop preventive measures against ignition. Laboratory experiments have dealt with the production and effects of frictional heat and sparks between rocks, steel, and light metals; sliding friction, direct impact and frictional impact between surfaces; stationary and flying sparks; sparks produced by picks, shovels, and other hand tools and by cutting machines; the effects of gas composition and oxygen content of the atmosphere; the role of speed of contact or energy release and of other parameters. Tests were made with falling weights against targets; high-speed impact of metal spheres against objects; pendulum-type friction devices; rotating wheels; electrically heated particles of metals in gases; and under other conditions.

Some of the earliest experiments studied the ignition of firedamp by the heat of impact of rocks. When the edge of a block of sandstone was placed against a revolving wheel of the same material, it was found that ignitions could be obtained easily and that weak mixtures of methane and air were easier to ignite than rich mixtures. Comparatively small energy was needed for the ignition, which was not produced by sparks but by a heated area on the rock surface at the point of contact. Some tests showed that firedamp can be ignited by hot particles thrown off by the abrasion of sandstone rocks, but such ignitions were only obtained when the heat was sufficient to fuse the stationary rock and a heated area on its surface, which was itself capable of igniting the gas. No sharp distinction could be made between the different sandstone rocks tested, but the quartzitic types appeared to produce ignitions most readily. The relative velocities of these rocks necessary to cause ignition of firedamp on collision was found to range from about 8 to 25 feet per second.

In experiments with hand picks against sandstone, ignitions were obtained with short, sharply delivered glancing strokes. This produced "stationary" sparking, that is, there was no shower of sparks through the explosive gas, but a localized yellow flash was observed at the moment of impact and over the area of contact of the pick point against the rock and a few red-hot particles moved slowly for a short distance at the surface of the rock as the face of the pick slid over it. If the blow produced a shower of sparks, firedamp did not ignite. Quartzitic sandstones were found to be most incendive in tests of this type, but some ignitions were obtained with sandstone of less uniform character classed as micaceous but containing quartzitic patches. Ignitions were obtained by the heated edge of a steel rod pressed against a rapidly revolving wheel of hard quartzitic sandstone. Tests with coal cutter picks set at the circumference of a rapidly revolving rock wheel, ignited firedamp by heating the rock surfaces.

In further tests ignitions were produced when the bits of chain or bar coal cutters made shallow cuts into quartz-bearing or siliceous sandstones, producing localized sparking in the form of red streaks or violent red flashes at the points of contact between the bits and the rock. No ignitions were obtained when similar cuts were made in pyrites or ironstone. In recent experiments on the effect of

orientation between the impacting steel and sandstone rock surfaces, it was found that ignition probability is very low at normal impact, but increases steadily as the angle is reduced to about 15 degrees -- the smallest angle investigated.

For many years firedamp could not be ignited experimentally by contact of metals with pyritic rocks. However, several ignitions in coal mines were known to have occurred when picks cut into pyrite nodules. As a result, at one time instructions were issued that if iron pyrite nodules were encountered during cutting the machine was to be stopped and the nodule cut out by hand. Finally, a successful experiment was developed in which a rubbing action was applied to the pyrite rather than a cutting or a glancing blow. It was established that firedamp mixtures are easily ignited by rubbing blunt picks or pick boxes against pyrites. The rubbing action reduces some of the pyrite to a fine powder and heats it to between 200° and 300° C., at which temperatures the powdered pyrite oxidizes rapidly, ultimately giving a flame of burning sulfur that ignites the firedamp. The tests showed that worn picks are more dangerous than new picks. Cutters with worn picks require more power with greater release of heat; they produce more fine coal dust, which induces the release of more gas. If a machine encounters hard rock strata the picks can be worn in a few minutes.

The experiments showed that from the standpoint of ignition hazard owing to contact between metal and rocks, it makes little difference whether the picks are made of steel or tungsten steel or whether they are tipped with sintered tungsten carbide or made of bronze or special nickel-chromium steel. The character of the rock is the most important factor.

Experiments showed that ignitions of firedamp during under-cutting could be prevented by introducing enough carbon dioxide into the cut to insure a CO_2 concentration of about 25 percent in the atmosphere around the jib of the coal cutter.

Friction between iron or steel surfaces was found to ignite firedamp only with great difficulty, even when it produced a shower of sparks. If the sparks are concentrated by a wooden or metal shield, ignition occurs more readily. At speeds of contact of about 30 feet per second or more between the metal surfaces, ignitions resulted when the friction was great enough to raise the temperature of the steel to a white heat. Experiments in which a mild steel bar was cut by a hard steel wheel at a peripheral speed of 500 feet per minute showed that the probability of ignition of methane increased almost linearly with the oxygen content of the gas mixture. As the carbon content and hardness of the steel bar was increased, ignition became easier, and less enrichment of the air with oxygen was necessary to produce ignition. Ignition also became easier as the speed of cutting wheel increased. Friction between some metal surfaces, as in machine bearings, is dangerous for other reasons. It can heat coal or other combustible dusts to a glow or smoldering temperature, which in turn can result in a fire or possibly an explosion.

In recent years much work has been done on the ignition hazard from friction and impact between light alloys and steel. Under certain conditions an exothermic reaction of the thermit type results when rusty steel painted with aluminum is struck with a piece of steel. In practice most commercial paints contain a bonding medium, which when new interposes a barrier between the reacting surfaces and lessens the hazard. Preheating was found to deteriorate the paint film and increase the potential hazard. It was suggested that a similar deteriorating effect might result from normal aging of the paint. Experiments on the effect of aluminum smears on steel friction props have shown that much higher impact energies are

needed to ignite firedamp if the aluminum is smeared on a clean steel surface than if it is smeared on a rusty surface. Red lead or iron oxide mixed with aluminum paint increased the violence of sparking. However, use of these materials in a primer coat reduced the hazard. Zinc coating on steel appears to be safer than aluminum, owing to its lower melting point and lower affinity for oxygen.

A series of experiments were undertaken following an ignition of firedamp in a coal mine in which 10 men were burned, 1 fatally, when a drilling machine encased in a magnesium alloy fell and struck a steel girder. The investigation disclosed that highly incendive sparks are produced by frictional impact of magnesium alloys on steel. The highest ignition probability occurred when the alloy struck the steel plate an angle of about 50 degrees. Ignitions resulted in some cases when the 36-pound test piece fell from a height of only 1.5 feet before striking the steel plate.

In a later study the incendivity of sparks produced by the impact of various cast light alloys against steel was investigated. It was found that: (a) The gas mixture is ignited by combustion of eroded metal particles which burn to form a flash; (b) the size, intensity, and incendivity of the flash decreases with decrease in the magnesium content of the alloy (there is an appreciable hazard even with pure aluminum); (c) the mixture most easily ignited contains 6.4 percent CH_4; (d) the angle of impact is not critical, ranging from 35 to 55 degrees, and outside of these limits the ignition probability is reduced and the chance of ignition appears to be small for normal impact or sliding friction; (e) the surface condition of the steel target plate has a great influence on the incendivity of the sparks, possibly owing to differences in roughness of the surfaces.

Interesting research is being conducted at present in England by Bowden on the ignition of methane-air mixtures by electrically heated, hot metal particles. It has been found that very small particles (less than 1 microgram for aluminum and magnesium) heated to their ignition point are effective in igniting gas. The minimum size of particle depends on the composition of the gas. A methane-air mixture containing about 7 percent methane was the most readily ignited, as compared with a mixture containing 9.5 to 10 percent methane, which was most readily ignited by a small aerated flame.

The order of effectiveness of the different metals tested(aluminum, magnesium, titanium, zirconium, pyrophor, cerium, and thorium) is the same as their heats of combustion, and the required size of particles increases as the heat of combustion decreases. These results indicate that the important factor under these conditions is the amount of heat liberated by the burning particles.

Another phase of the investigation concerns ignition of methane-air mixtures by sliding friction such as exists between a rotating steel wheel and a stationary piece of metal. Under these conditions the ignition probability increases with the rubbing speed and with the pressure or load of the stationary metal against the wheel. The order of effectiveness of the metals does not depend only on their heat of combustion. The important factor is thought to be the size and character of the particles that are abraded from the rubbing surfaces and projected into the gas mixture. With effective metals such as zirconium and pyrophor, the detached metal particles were very small (50 to 100 micrograms). The titanium particles were quite small (2 to 10 micrograms), but no ignitions were obtained as these particles did not burn on leaving the surface. Aluminum, magnesium, and their alloys produced no visible sparks or gas ignitions; the rubbing metal was plastically deformed and smeared over the sliding surfaces. In this ignition process the flying particles

and not the rubbing surface govern the ignition, making the brittleness and mechanical properties of the metal very important. Normal impact between many pairs of metals, with high impact pressure, has produced no ignition of methane-air mixtures, although sparks have been observed with certain materials. This is thought to be due to the fact that local temperatures under such conditions are not very high and small metallic fragments are not detached too readily.

In a recent investigation conducted in two seams of a British coal mine, firedamp was diluted in the cut with compressed air and water sprays during overcutting. The experiment was made in dry and dusty seams. Two sets of sprays were used, one to spray the ingoing chain and the other to spray the outgoing chain. One spray attached to the cutter turret had 5 jets, 4 of which sprayed the machine turret, cutter chain, and roof and the end jet sent a powerful stream of water into the back of the overcut. A compressed-air line was incorporated in this spray so that compressed air was injected with the water, producing a heavy mist. The compressed-air pressure varied between 50 and 60 p.s.i.; the water pressure was 100 pounds.

During normal wet cutting operations in these tests the methane content ranged from 2.5 to 3.5 percent in one seam, and from 1.2 to 1.8 percent in the other. When the compressed air-water sprays were stopped, the methane content rose rapidly to the explosive range and beyond it; in some cases readings of up to 75 and 40 percent methane, respectively, were noted in the cuts of the two seams. According to reports from different collieries, similar percentages of methane have been encountered in cuts in other seams. The sprays are reported to fulfill the following important functions, which reduce the ignition hazard: (1) The methane content in the cut is reduced below the explosive range; (2) cuttings are thoroughly wetted, suppressing coal dust and reducing the explosion hazard; and (3) the cooling effect of the jets reduces the temperature of frictional sparks that may be produced during cutting. The tests indicate that after an extended period of idleness the sprays should be used to remove firedamp from the cut before the machine is put into action. During short periods of inactivity, even if it is necessary to stop the water sprays, a large volume of compressed air should be directed into the cut to prevent accumulation of firedamp which might be emitted suddenly.

FACTORS AFFECTING IGNITION HAZARD

The hazard of gas ignition by friction and impact depends on the nature of the contacting materials, the composition of the explosive gas, the available energy, and the type of contact. Research indicates that ignitions are produced most easily by friction between certain types of rocks. However, most mine explosions initiated by friction have resulted from contact between rocks and metals, as during undercutting of coal seams. Metal-to-metal contacts generally produce less incendive sparks than metal-to-rock contacts, but under some conditions, friction between light metal alloys and steel produces highly incendive sparks.

In all types of frictional heating the ignition probability depends on the rate of energy release, which is determined by the mass and speed of the contacting objects and the frequency of contact, the concentration of heat near the point of contact, the orientation of the surface at the time of contact, and the methane and oxygen content of the atmosphere. Weak mixtures of methane below the stoichiometric limit are more readily ignited by friction than rich mixtures, and turbulence appears to increase the ease of ignition. In contact between metals and rocks, frictional impact at small angles produced the most incendive heating; in contact between light alloys and steel, angles of 35 to 55 degrees were most hazardous; and in some metal-metal contacts sliding friction was worst. Normal or direct impact rarely produced firedamp ignitions.

Of the rocks encountered in coal mines, siliceous or quartz-bearing sandstones present the greatest frictional ignition hazard; they are closely followed by iron pyrites. Some micaceous sandstones also have been found to constitute a hazard. Shales are considered less dangerous than sandstone, but some bituminous sandstones, which look like shales, can produce incendive sparks. It has been found that rocks with less than 35 percent quartz can give dangerous sparks. There is some indication that the moisture content of rocks may affect their incendivity.

In contact between rocks and metals the nature of the rock is far more important than that of the metal. Although little if any difference was observed between various steels in contact with rocks, in high-speed machine operations the surface hardness of the metal might have an effect. Sharp glancing blows proved most effective in producing ignitions by friction between steel and sandstone. In contact between steel and pyrite, the most hazardous conditions occurred during rubbing or sliding friction, which produces fine dust. In tests with cutters, the sharpness of the bits was found to be an important factor. Blunt bits are more hazardous than sharp bits because they produce more fine coal dust and upon encountering pyrite may produce and ignite pyrite dust. Another important factor in cutting or drilling is overloading machines; this can produce much heat and bring about conditions that lead to ignition.

In metal-to-metal contact the properties of the more readily oxidizable metal normally determine the degree of ignition hazard. The hardness, melting point, ignition temperature, specific heat, heat conductivity, and brittleness of the metals all play a role, in that they determine the size, duration, temperature, and heat capacity of the incendive sparks. Increase in the carbon and silicon contents of steels and rust on the steel surfaces promote the formation of incendive sparks during friction. Painting the steel surface, as with zinc coating, reduces the incendivity. Painting with aluminum may increase the ignition hazard, particularly on rusty steel.

During friction between light alloys and steel, the ignition hazard increases with the magnesium content of the alloy. Contact between aluminum and steel, particularly rusty steel, also gives incendive sparks under some conditions. The incendivity of metals seems to be related to their reactivity, as indicated by their position in the electropositive series of metals. In British coal mines the use of light metal alloys is being restricted or entirely discontinued.

MECHANISM OF FRICTIONAL IGNITION

As has been indicated, broadly speaking the ignition of gas by friction can be initiated either by heating near the points of contact or by heat transfer to the gas from the hot abraded fragments (frictional sparks). Despite extensive research there is no general agreement on the exact mechanism of the ignition process. This is due in part to the complexity of the problem and in part to the fact that the mechanism varies according to the circumstances.

Consider first frictional ignition by metal-to-rock contacts. In friction between steel and pyrite, the process requires production of fine pyrite dust and heating to a point where autooxidation starts; as this proceeds and the iron sulfide is converted to iron oxide, the temperature of the dust particles rises until a flame of burning sulfur appears and ignites the gas. A similar mechanism of ignition probably exists when excessive friction during cutting or drilling in a coal seam produces and heats very fine coal dust whose smoldering and eventual ignition can initiate a firedamp explosion. This has reportedly occurred in at least one mine. Frictional ignitions resulting from contact between steel and

siliceous sandstone are more difficult to explain. It is agreed that they are due to heating at the surface of the rock and not to frictional sparks. According to some observations in Germany, the small abraded particles of steel adhere to the sandstone at the points of contact (See p. 8); as these are heated by friction, they oxidize and eventually ignite, initiating the gas explosion. If this is so, the nature of the steel should play a role in determining the ease of ignition, yet, experiments in Germany and England failed to establish differences between steels, and in some tests even copper alloys were reported to give ignitions readily. English tests make no mention of metal particles adhering to the rock surfaces. The question therefore remains, what is the mechanism of ignition and why is quartz so much more effective in producing incendive sparks than other rocks. The belief that hardness and low heat conductivity of the quartz are the governing factors has not been substantiated. Tests with harder rocks, such as carborundum and corrundum (which is probably a poorer thermal conductor than quartz) produced considerable sparks in frictional contact with steel, but firedamp was not ignited. An explanation suggested by Wynn is that the incendivity of quartz may be connected with its piezoelectric properties, which cause electrical discharges when quartz crystals are broken.

Frictional heating between light alloys and rocks has received little attention so far. As these metals are highly reactive, it is possible that their composition and other properties rather than the nature of the rocks may govern the probability of ignition.

The mechanism of ignition during friction and impact between rocks has not been explained satisfactorily. It is known that ignition is initiated at or near the points of contact, apparently by the heated surfaces.

In friction between metal surfaces there are many considerations. Bowden has found that with so-called stationary sparks of heated metal particles in an explosive gas, the size of particles required to produce ignition is related to the heat of combustion of the metal. This is pertinent in certain types of friction, for example, worn bearings, where there is considerable heating but no shower of sparks. In the familiar frictional spark process a certain amount of energy must be expended in shearing off the small particles of metal that are the nuclei of the sparks. This energy is transformed into heat, which raises the temperature of the particles. If the sparks are composed of relatively inert material their temperature may not exceed their melting point. With metals that are reactive in air, the freshly exposed surface oxidizes at the elevated temperature, and this further increases the temperature until the particle is heated to incandescence and is capable of igniting the gas. Aside from the chemical reactivity and the heat of combustion, several properties of the contacting metals are important in this process; brittleness, hardness, heat conductivity, and specific heat. Sparks of zinc and steel, which do not burn very readily in air, fail to reach as high temperatures as particles of magnesium and aluminum, which have low ignition temperatures and oxidize rapidly in air. This helps to explain why in some types of friction of light alloys with steel highly incendive sparks are produced. The part played by rust on steel surfaces has not been studied yet.

In contact between dissimilar metals, the one that is more readily oxidized generally determines the incendivity of the sparks. The size of the particles composing the sparks is important. Small particles are usually more incendive because they oxidize rapidly and have higher temperatures. If the particles are too small they may not have enough heat capacity and may lose heat faster during motion.

The mechanism of gas ignition by friction when an aluminum-coated steel surface is struck with a tool, is thought to be a thermit reaction in which aluminum and iron oxide react rapidly. However, recent experiments indicate that the reaction process may be only normal oxidation of the abraded aluminum particles in air, possibly aided somewhat by reaction between the aluminum and iron oxide.

PREVENTION OF GAS IGNITIONS BY FRICTION

Experience and research have demonstrated that friction and impact between machines and minerals can produce firedamp ignitions during many operations in coal mines. Although the presence of frictional sparks is a warning of potential danger, it should be remembered that hot spots on the contacting surfaces can cause ignitions without visual sparking. To avoid ignitions, gas accumulation and frictional heating or frictional sparks must be prevented. A list of measures proposed for this purpose is given below. Based largely on European experience and research, some of these measures cannot be applied practically to our mechanized mining conditions.

(1) No coal cutting, roof caving, or other operations conducive to the production of frictional sparking should be performed in the presence of detectable gas in the mine atmosphere near the face. A check for gas should be made before such work is started and at frequent intervals thereafter.

(2) Special attention should be given to proper roof-control measures designed to reduce the formation of incendive sparks by breaking of hard sandstone beds.

(3) In general, ventilation at face areas in gassy mines where machines are used should be greatly improved. To accomplish this, auxiliary ventilation should be provided where necessary.

(4) Special ventilating and dust-suppressing arrangements and firedamp detectors should be provided on mining machines.

(5) Gas should be removed from cuts with large volumes of air as rapidly as it forms to keep the methane content below the lower explosive limit. Uncontrolled ventilation with insufficient air can make conditions more hazardous by bringing a mixture that is initially too rich into the explosive range.

(6) A survey should be made to determine the rate of gas emission and the composition of the atmosphere at various locations in cuts before ventilation plans are made. Consideration should be given to the possible sudden increase of gas output.

(7) Water should be injected on both sides of cutter bars, or better still compressed air-water sprays, which direct a strong mist into cuts, should be installed on mining machines. Such air-water sprays are more effective than either air or water alone. The mist dilutes the methane as it issues into the cut near the cutter bits, it wets the cuttings, and cools any frictional sparks that might form. The sprays should be started some time before cutting commences.

(8) Inert gas (carbon dioxide or nitrogen) should be introduced into cuts to render the atmosphere around the cutter bars nonexplosive. This last is an early recommendation that has not been put into practice. -- In large mining machines consideration might be given to the introduction of inhibitors into cuts.

(9) Dry cutting and drilling should be avoided in gassy coal mines.

(10) Special care should be exercised in cutting seams adjoining siliceous rocks and those containing inclusions of iron pyrite. Similar care should be exercised in areas where faults or other gas feeders may be present.

(11) Whenever practicable, a cutting level or horizon should be selected that is free of any meterial that might produce sparks.

(12) Where practicable, several inches of coal should be left at the roof and on the floor to avoid cutting into adjoining hard rocks.

(13) To avoid excessive frictional heating mining machines should not be overloaded. When smoldering or other signs of heating are observed, the machine should be stopped.

(14) Unnecessary stopping should be avoided once cutting or drilling has begun, as this permits gas to accumulate in the cuts. During short periods of idleness, compressed air should be directed into cuts to prevent gas accumulation.

(15) The speed of cutting tools should be reduced.

(16) Mining machines should be operated in such a way as to limit the production of fine coal dust.

(17) Continuous mining machines, which make narrow cuts, should not advance too deeply into the seam unless there is provision for rapidly and adequately diluting and removing any gas that occurs.

(18) Use of high-silicon steel should be avoided, and rust on surfaces of steel roof supports and other structures prevented. The latter can be accomplished by using galvanized steel, or by applying zinc metal sprays or zinc chromate coating.

(19) Aluminum paints should not be used on steel surfaces in coal mines.

(20) Use of magnesium-base alloys should be limited or prohibited entirely. Care should be exercised to avoid friction and impact of all light metal alloys with steel and with hard rocks.

(21) Workmen should be warned of the potential hazards of frictional sparks, and they should avoid rapid, repeated blows with picks or tools at the same spot on rocks or metals.

(22) Attention should be given to frictional heating and sparking when using very hard bits and drills in high-speed mining machines.

(23) Fire-extinguishing facilities at mechanized coal faces should be improved. Water hose, with an ample supply of water, or other effective fire extinguishers should be provided.

The most important of the above recommendations probably relate to the provision of adequate ventilation at the coal face; the use of enough air and water in cuts; frequent checking for gas in the atmosphere; design and use of mining machines so as to facilitate rapid removal of gas; avoidance of overheating of

cutting and other machines; and avoidance, insofar as possible, of hard rocks during cutting and drilling.

BIBLIOGRAPHY

1. MAYER, J. Versuche über die Entzündlichkeit der Grubengase durch Funken: Oesterr. Ztschr. Berg- u. Hüttenw., vol. 34, June 12, 1886, pp. 379-82, 398-401.

2. MINISTRY OF FUEL AND POWER. Annual Reports of Safety in Mines Research Board (recently changed to Safety in Mines Research Establishment) Great Britain, 1924-55.

3. ALLSOP, G. A., and WHEELER, R. V. The Ignition of Firedamp by Pyrites During Coal-Cutting: Trans. Institution Min. Eng. (Great Britain), vol. 96, 1939, pp. 310-316.

4. SCHULTZE-RHONHOF, H. and WEICHSEL, L. Die Gefahr der Schlagwetterzündung durch Metallische Reibungs- und Schlag-Funken: Mitteilungen der Westfälischen Berggewerkschaftskasse, Sept. 1951, 12 pp.

5. Reports of H. M. Chief Inspector of Mines, for the years 1951 and 1952, Ministry of Fuel and Power, Great Britain.

6. WYNN, A. H. A. The Ignition of Firedamp by Friction: S. M. R. E. Research Report No. 42, 1952, 23 pp.

7. KINGMAN, F. E. T., COLEMAN, E. H., and ROGOWSKI, Z. W. The Ignition of Inflammable Gas by Sparks From Aluminum Paint and Rusty Steel: Jour. Appl. Chem., vol. 2, August 1952, pp. 449-56.

8. TITMAN, H. The Ignition Hazard From Sparks From Cast Alloys of Magnesium and Aluminum: S. M. R. E. Research Report No. 90, 1954, 24 pp.

9. TITMAN, H., and Wynn, A. H. A. The Ignition of Explosive Gas Mixtures by Friction: S. M. R. E. Research Report No. 95, 1954, 22 pp.

10. CARVER, J. Firedamp in Machine-Cut Kervings: Iron and Coal Trades Rev., vol. 169, July 9, 1954, pp. 87-91.

11. YOUNG, M. H. Ventilated Auger Mining at Haucknall Colliery: Trans. Institution Min. Eng. (Great Britain), vol. 114, January 1955, pp. 337-365.

12. BOWDEN, F. P. Recent Studies of Metallic Friction: Chartered Mech. Eng., vol. 2, February 1955, pp. 86-101.

Bureau of Mines
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EQUIPMENT FOR ANALYZING MINE ATMOSPHERES, WITH SPECIAL REFERENCE TO HALDANE-TYPE APPARATUS

By H. A. Watson and L. B. Berger

United States Department of the Interior — January 1956

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UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
Thos. H. Miller, Deputy Director

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by

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SUMMARY

This circular, which is a revision and combination of two previous publications,3 4/ presents information on the different types of equipment that may be used to analyze mine atmospheres, with particular reference to the application and limitations of each type. Such information is frequently requested by mining companies, State mining departments, and other agencies concerned with safety in mining who wish advice regarding methods of analysis of mine atmospheres and the equipment necessary for establishing laboratories for that purpose. Since the Haldane-type apparatus is particularly applicable to the accurate determination of carbon dioxide, oxygen, and combustible gases such as methane in mine atmospheres, that apparatus and the method of operation are described in detail. The circular presents results of a critical study of the accuracy attainable with the Haldane-type apparatus in the determination of methane in concentrations of the order of 0.25 percent, by volume. Analytical procedures involved in the other methods discussed are presented in publications referenced in this circular. Information is given also on the various accessory equipment needed in a laboratory for the analysis of mine atmospheres, and suggestions on laboratory design are included.

INTRODUCTION

The analysis of mine atmospheres plays an important part in promoting safety and maintaining safe conditions in mining operations, particularly in coal mining, where the flammable gas methane presents a continuous hazard in some mines and may be encountered unexpectedly in others.5/ Methane has been encountered also, often unexpectedly and with disastrous results, in noncoal mines and in tunnels under

3/ Berger, L. B., and Schrenk, H. H., Bureau of Mines Haldane Gas Analysis Apparatus: Bureau of Mines Inf. Circ. 7017, 1938, 24 pp.
4/ Berger, L. B., and Schrenk, H. H., Laboratory Equipment for the Analysis of Mine Atmospheres: Bureau of Mines Inf. Circ. 7441, 1948, 18 pp.
5/ Forbes, J. J., and Grove, G. W. (rev. by McElroy, G. E., Watson, H. A., Coggeshall, E. J., Dornenburg, D. D., and Berger, L. B.), Mine Gases and Methods for Detecting Them: Bureau of Mines Miners' Circ. 33, 1954, 82 pp.

construction.[6 7] The determination of methane is vitally important in underground operations known to liberate this gas because ventilation must be maintained in adequate quantity, and be properly coursed, to dilute and remove the gas as it is liberated. Of equal importance is the search for and detection of methane, even in trace amounts, in mines not hitherto suspected of being gassy, as experience has proved that in many such mines the liberation of methane may increase suddenly and without warning, creating a definite hazard and frequently resulting in disaster.

Other conditions that must be considered in respect to underground atmospheres are accumulations of carbon dioxide, depletion of the oxygen content of the air, and the possible presence of toxic gases such as carbon monoxide and oxides of nitrogen.

Because of the diverse nature of the constituents of mine atmospheres, and the various concentrations in which these constituents may occur, no one type of apparatus is suitable for their determination under all conditions that may be encountered in underground operations. If analytical results of usable accuracy are to be obtained, equipment and methods must be selected that are most appropriate for study or examination of the particular situation that exists. The following text discusses these matters in respect to composition of mine atmospheres, methods of sampling, description of analytical apparatus, and methods of procedure.

TYPES OF ANALYSES THAT MAY BE REQUIRED IN DETERMINING THE COMPOSITION OF MINE ATMOSPHERES

The analysis of mine atmospheres may be divided into two general classes with respect to the locations at which the atmospheres exist, namely, in ventilated and unventilated places.

Analysis of the Air of Ventilated Places

In coal mines and in some other underground operations the percentage or concentration of methane in the air of ventilated places is of chief concern because of the potential hazard of explosion. The oxygen and carbon dioxide contents of the air are important also in that significant reductions in oxygen or increases in carbon dioxide may affect the health and efficiency of persons at work in such atmospheres.

The air of ventilated working places also may be contaminated by noxious or poisonous gases that are produced or liberated during mining. Carbon monoxide may be introduced into the air when explosives or internal-combustion engines are used or by leaks from sealed fire areas. The toxic oxides of nitrogen may be produced by explosives and are present in the exhaust gases of internal-combustion engines.

The following data are cited in regard to the concentrations or percentages of these different gases that must be considered in analyzing mine atmospheres:

The Federal Coal Mine Safety Act[8] contains the provision that "all active underground working places in a mine shall be ventilated by a current of air

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6/ Harrington, D., and Denny, E. H., Gases That Occur in Metal Mines: Bureau of Mines Bull. 347, 1931, 21 pp.

7/ Harrington, D., and Ash, S. H., Some Essential Safety Factors in Tunneling: Bureau of Mines Bull. 439, 1941, 61 pp.

8/ Federal Coal Mine Safety Act: Title I, May 7, 1941, Public Law 49, 77th Congress; Title II, July 16, 1952, Public Law 552, 82d Congress.

containing not less than 19.5 per centum of oxygen, not more than 0.5 per centum of carbon dioxide, and no harmful quantities of other noxious or poisonous gases."

This act also states, in substance, that if 0.25 percent or more of methane is found by air analysis in any open workings of a coal mine within the purview of the act, that mine shall be subject to the provisions of the act relating to the use of permissible equipment.

In regard to the toxic gases, it is generally considered that 0.01 percent by volume of carbon monoxide is the maximum concentration permissible in the air of working places in which exposure does not exceed 8 hours daily. The similar maximum for total toxic oxides of nitrogen is 0.0025 percent (25 parts per million, by volume), although a limit of 5 parts per million has been suggested for nitrogen dioxide.9/

From the foregoing it is evident that the quality of the air of working places must be examined carefully to meet these requirements and that the methods used in analyzing the air must be quite accurate and sensitive if analytical results of any value are to be obtained. For example, if the return air of a coal mine actually contains 0.20 percent methane, it would be meaningless to analyze this air by a method whose accuracy is no better than 0.2 to 0.3 percent, because the results might be in error by an amount equal to or greater than the actual percentage of methane present. If the methane content of the air, as determined by analysis, is to be used in conjunction with a measured air-quantity value to calculate volume of methane liberated by the mine in a given time, the calculated result will be of little or no value unless an analytical method of maximum accuracy is used in determining the methane.

Similarly, if carbon monoxide is to be determined in the air of working places from the standpoint of possible effects upon persons at work in these places, the analytical method must be sensitive to at least 0.01 percent of carbon monoxide.

Methods suitable for analyzing the air of ventilated mine workings are described in a following section.

Analysis of Atmospheres of Unventilated Places

The term "unventilated places" refers to (a) face areas or dead ends through which the ventilating air is not coursed, (b) open, unventilated, abandoned sections, and (c) the areas behind fire seals or gas seals. The atmosphere in such places may contain considerable percentages of carbon dioxide and abnormal accumulations of nitrogen, and may be depleted of oxygen. The methane content may be below, within, or above the flammable or "explosive" range, and, in the case of fire seals, carbon monoxide may be present in concentrations ranging from traces to several percent. Certain of the gases in these atmospheres may be present in percentages beyond the range of equipment suitable for the analysis of air from ventilated places, and, when such is the situation, analytical apparatus designed to accommodate these higher concentrations of gases must be used. Some decrease in accuracy of determination may result from the use of such apparatus, but a high degree of accuracy is not required in analyzing the atmospheres of many unventilated places. For example, if a sealed fire area in a coal mine actually contains 35 percent methane, an error of a few

9/ American Conference of Governmental Industrial Hygienists, Threshold Limit Values for 1954: Arch. Ind. Hyg. Occup. Med., vol. 9, 1954, pp. 530-534.

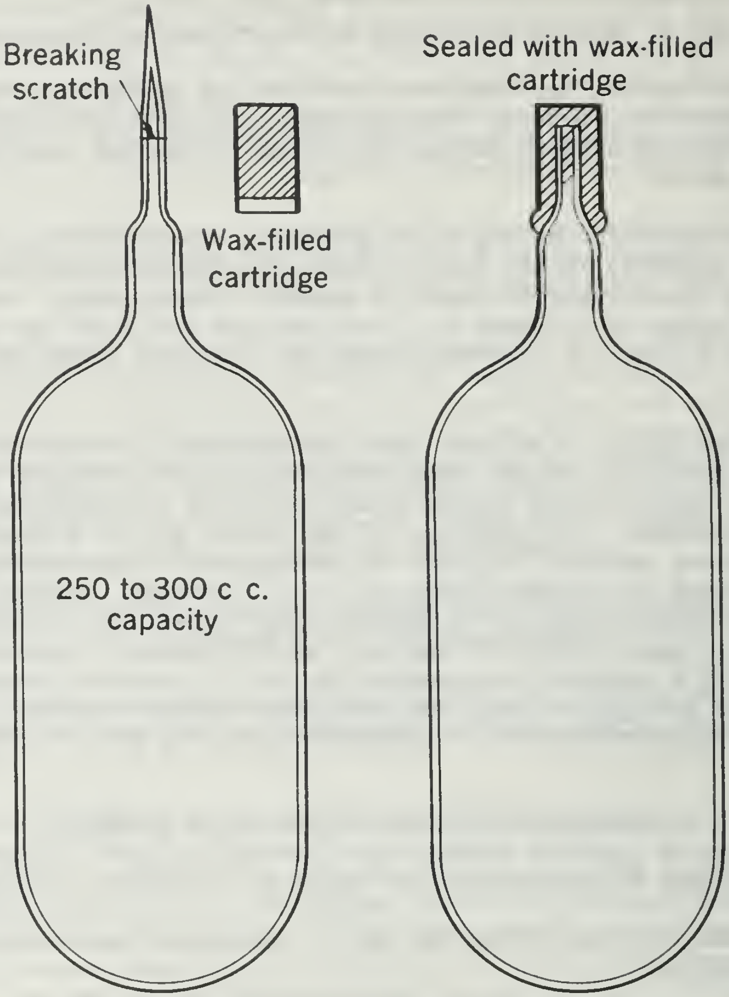


Figure 1. - Vacuum-type sample container.

tenths of a percent or even as much as 1 percent would have no significance or importance in practical interpretation of the analytical results.

One exception to the above statement is in the determination of carbon monoxide in sealed fire areas. When an active fire in a coal mine is first sealed, the carbon monoxide content of the atmosphere in the sealed area may be 1 or 2 percent or more, and extreme accuracy in determination is not necessary, as such concentrations of carbon monoxide may be interpreted only as indicating that the fire still is active. As the fire nears extinguishment and the area cools, the carbon monoxide content will decrease gradually and finally will reach zero if the area is allowed to remain sealed long enough. In such instances it is important to determine mere traces of carbon monoxide, and an analytical method sensitive to at least 0.01 percent of carbon monoxide should be used.

Methods and equipment suitable for the analysis of atmospheres from unventilated places are described in a following section.

The foregoing discussion is intended to show that no one type of equipment or method is applicable to the analysis of all types of mine atmospheres. Suitable analytical results will be obtained only when the equipment or method used is the proper one to fit the existing conditions.

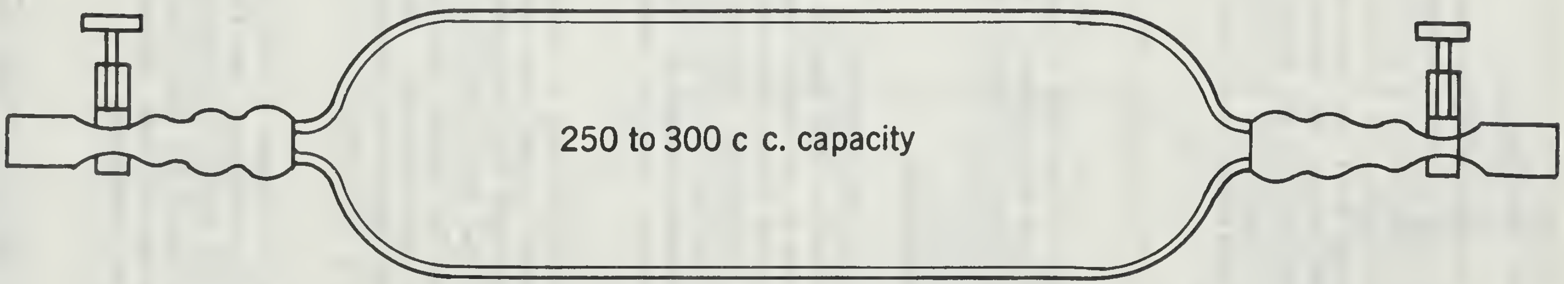
EQUIPMENT FOR SAMPLING MINE ATMOSPHERES

The selection of proper equipment for sampling mine atmospheres is just as important as the choice of analytical methods, because no matter what degree of care and skill may be exercised in the analysis, the results can be no better than the sample. A sample that has been improperly collected, or one whose composition has changed because of faults in the sample container, is worthless, and the results obtained by analysis of such a sample may be seriously misleading. The subject of sampling mine atmospheres is discussed in detail in another Bureau of Mines publication;[10] the following information applies to the various types of containers that may be used in collecting samples of mine atmosphere:

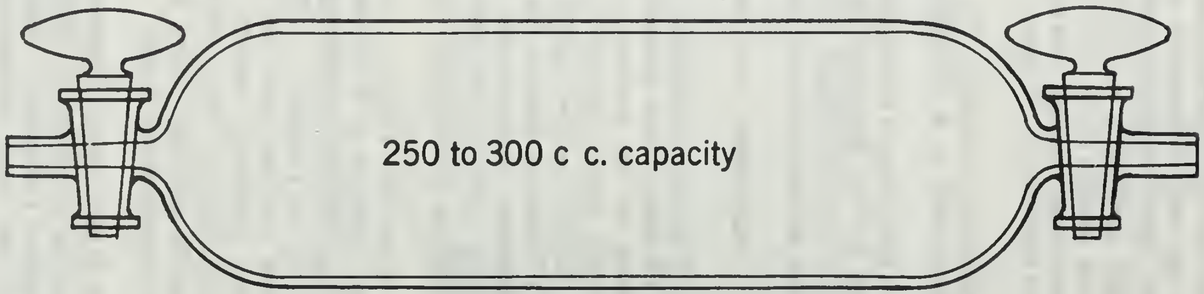
A vacuum-type container (fig. 1) is used almost exclusively by the Bureau of Mines for collecting samples of mine atmosphere, because it has been found most suitable from the standpoints of freedom from leakage, ease of transportation underground, and durability in shipment. After the sample has been withdrawn from this type of container and the analysis has been completed, the opened container is sent to a glass blower for cleaning, repair, reevacuation, and resealing. Use of this type container is practicable only where the necessary facilities for glass blowing and reevacuation can be arranged for, as the cost of a new container for each sample collected would be unreasonably high.

Other types of glass sample containers are shown in figure 2, one type being closed by rubber-tubing connections clamped shut by screw clamps, and the other type being fitted with glass stopcocks. Such containers are rather vulnerable to breakage, and the type fitted with rubber-tubing closures should be used only when the samples will be analyzed soon after collection as gas may diffuse through the rubber and be lost if several days elapse between sampling and analysis.

10/ Berger, L. B., and Schrenk, H. H., Sampling and Analysis of Mine Atmospheres: Bureau of Mines Miners' Circ. 34, 1948 (rev.), 103 pp.



Type A



Type B

Figure 2. - Gas- or liquid-displacement type sample container.

Metal containers of the same general design as those shown in figure 2 may be used and are more durable than the glass containers. The metal stopcocks are more likely to leak than glass cocks, but if inspected and greased frequently will serve satisfactorily. The metal containers should be of brass, zinc, or other nonferrous metal. Iron containers are likely to remove oxygen from the sample through rusting of the interior of the container, and water must be used11/ to displace sample from the metal-type container, and some carbon dioxide is likely to be dissolved from the sample.

Some mining companies use rubber bags as containers for samples of mine atmosphere, inflating the bags and clamping off the inlets at the desired sampling locations. The bags are reported to be satisfactory for sampling atmospheres that are essentially normal air containing small percentages of methane or carbon dioxide. It seems possible, however, that if atmospheres containing high percentages of methane or carbon dioxide were sampled in this manner, some loss of these gases might occur unless the samples were analyzed soon after collection.

Bottles of the type used by druggists for magnesium citrate solution may be used as sample containers. This type of bottle is fitted with a glass stopper seating on a rubber gasket or washer and held in place by a strong spring clamp. The rubber gaskets must be in good condition to insure a gas-tight seal.

Specially prepared evacuated glass containers, as shown in figure 3, are used to collect samples for determining oxides of nitrogen. A small volume of liquid absorbent for oxides of nitrogen is placed in the container before it is evacuated and sealed. Preparation of these containers is described in detail in a Bureau of Mines publication.12/ A sample collected in this type of container may be analyzed only for oxides of nitrogen; if it is desired to determine other constituents of the atmosphere at the same location, an additional sample must be collected in one of the conventional containers.

The selection of sample containers depends on the type of analyses to be made, the method of transportation of samples between mine and laboratory, the time that may elapse between sampling and analysis, and, in the case of the vacuum-type containers, the availability of facilities for evacuating and sealing the containers.

RECORDING OF DATA

In a laboratory where samples of mine atmosphere are to be analyzed as a continuous operation, a systematic procedure should be adopted for identifying the samples and recording this information and the analytical results. A suggestion along this line is shown in figure 4 (top). The required information may be inserted on the label by the collector of the sample at the time of sampling. The collector also fills in the required information on the card shown in figure 4 (bottom), which accompanies the sample container to the laboratory.

When the sample container and card are received at the laboratory, a serial number may be stamped on the card and also on a form for recording the analytical data (fig. 5). This serial number thereafter identifies the sample and the results

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11/ If mercury is used as the displacing liquid, metal sample containers will be damaged by amalgamation.

12/ Beatty, R. L., Berger, L. B., and Schrenk, H. H., Determination of Oxides of Nitrogen by the Phenoldisulfonic Acid Method: Bureau of Mines Rept. of Investigations 3687, 1943, 17 pp.

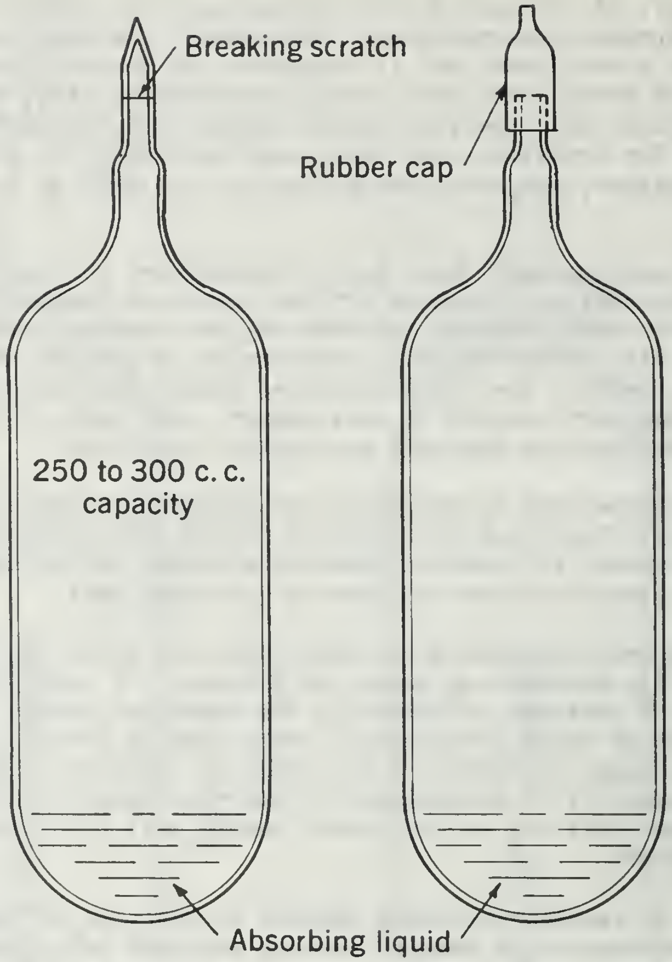

Figure 3. - Special evacuated container for sampling for oxides of nitrogen.

851

LAB. NO.________ BOT. NO.________
MINE________________________
____
DATE________ HOUR________
LOCATION______________________
____
COLLECTOR_____________________
DATE REC'D.____________________

Figure 4. - Label and number on vacuum-type sample container.

MINE ATMOSPHERE SAMPLE RECORD

GENERAL DATA

Mine ....
Operator .... Coal bed ....
State .... County .... Town ....
Collector (name and title) ....
Send results of analysis to ....

SPECIFIC DATA

Bottle No. .... Laboratory No. .... Date received ....
Kind of sample ....
Location in mine ....
....
Date and hour sampled .... Air quantity ....
Pressure on seal .... Barometer (inside) ....
Estimated methane .... Analysis desired ....

See instructions on other side 16—17007-1

Figure 4a. - Mine atmosphere sample record that accompanies sample container.

	Burette Reading	Corrected Reading	Difference	Percent	Burette Reading	Corrected Reading	Difference	Percent	Burette Reading	Corrected Reading	Difference	Percent
Volume of sample taken												
Carbon dioxide												
Unsaturated hydrocarbons												
Oxygen												
Hydrogen by CuO at 300° C												
Carbon monoxide by CuO at 300° C												
Oxygen (or air) added												
Total volume												
Volume after burning												
Volume after CO_2 absorption												
Volume after second burning												
Volume after second CO_2 absorption												
Total contraction												
Total CO_2												
Residual O_2												
Total oxygen												
Methane												
Ethane												
Total paraffins												
Nitrogen												

Apparatus No. ____________ *Date* ____________ *Chemist* ____________

Figure 5. - Form for recording data in the analysis of mine atmospheres.

of its analysis. After the sample has been analyzed and the results have been reported, the data card and the analysis form should be filed. It is preferable to keep all original analytical data on file in the laboratory. Any suitable form may be used in reporting the analytical results so long as the sample is properly identified as to location, date of sampling, etc.

EQUIPMENT AND METHODS FOR THE ANALYSIS OF MINE ATMOSPHERES

Haldane Gas-Analysis Apparatus

The Haldane gas-analysis apparatus used by the Bureau of Mines is patterned after the device developed by Haldane13/ and differs from it only in structural modifications that have been added to facilitate operation and simplify construction.

The apparatus was developed to permit determination of carbon dioxide, combustible gases, and oxygen with a degree of accuracy not attainable with apparatus of the types ordinarily used for the analysis of fuel gases, flue gases, and similar mixtures. The Haldane apparatus is used by the Bureau of Mines chiefly in analyzing air samples collected in coal and metal mines and other underground workings and is applied also in analyzing many other types of gas mixtures when accurate determination of certain constituents is desired.

Accuracy of Haldane Apparatus

The Haldane apparatus is well suited to the routine determination of gaseous constituents normally present in mine atmospheres when due consideration is given to the attainable accuracy of results, the limited volume of sample generally available for analysis, and the time required for analysis. Limitations of application are discussed in a subsequent section. In the routine analysis of mine atmospheres as performed in Bureau of Mines laboratories successive portions of each sample analyzed for carbon dioxide and for a single combustible gas shall agree within 0.02 to 0.03 percent by volume, and, for oxygen, within 0.05 percent by volume. In a majority of cases only two analyses are required to obtain such agreement. Many years of experience have proved these limits of precision to be practicable and readily attainable. The greater tolerance allowed for oxygen results from certain limitations of the oxygen-absorbing reagent over and above the normal experimental variations in measuring gas volumes (burette readings may be made to $\pm$ 0.002 ml.).

Since finding 0.25 percent or more of methane may result in the classification of a coal mine as gassy,14/ a study of the accuracy of the Haldane method for determining methane concentrations of this order has been made. Forty-four samples of three test mixtures containing known concentrations of methane in air were analyzed. Table 1 shows the distribution of values obtained experimentally in relation to the true values. The methods of procedure in the study of accuracy are presented in detail in an appendix to this information circular.

13/ Haldane, J. S., Some Improved Methods of Gas Analysis: Jour. Physiol., vol. 22, 1898, pp. 465-480; A Rapid Method of Estimating Carbon Dioxide in Air: Jour. Hyg., vol. 1, 1901, pp. 109-114; Methods of Air Analysis: Charles Griffin and Co., Ltd., London, 1912. Revised and Reprinted 1918. Reprinted 1920. Revised, in collaboration with J. Ivon Graham, and reprinted in 1935. Foster, C. LeN., and Haldane, J. S., The Investigation of Mine Air: Charles Griffin and Co., Ltd., London, 1905, pp. 100-120.

14/ Federal Coal Mine Safety Act: Title II, July 16, 1952, Public Law 552, 82d Congress.

TABLE 1. - Summary of study of accuracy of determination of methane with Haldane-type apparatus

	Single methane determination		Average of two methane determinations on same apparatus		Average of 4 methane determinations--2 on each of 2 different apparatus		Average of 6 methane determinations--2 on each of 3 different apparatus	
	Number	Percent of total	Number	Percent of total	Number	Percent of total	Number	Percent of total
True value plus 0.03 percent	3	1.1	2	1.5	0	0	0	0
True value plus 0.02 percent	3	1.1	2	1.5	0	0	0	0
True value plus 0.01 percent	37	14.1	20	15.3	15	11.5	2	4.7
True value	112	42.8	68	52.0	84	64.6	32	74.4
True value minus 0.01 percent	92	35.1	37	28.2	30	23.1	9	20.9
True value minus 0.02 percent	13	5.0	2	1.5	1	0.8	0	0
True value minus 0.03 percent	2	0.8	0	0	0	0	0	0
Total	262	100.0	131	100.0	130	100.0	43	100.0

The deviation of a single determination of methane was no greater than ±0.03 percent, by volume, from the true value. The maximum deviation of the methane value derived by averaging 2 analyses on an individual Haldane apparatus ranged from +0.03 to -0.02 percent, by volume, from the true value. The maximum deviations of the methane values obtained by averaging 4 determinations (2 each on 2 individual apparatus) were +0.01 and -0.02 percent, by volume, from the true value. The methane value obtained by averaging 6 determinations (2 each on 3 individual apparatus) deviated by no more than ±0.01 percent, by volume, from the true value.

Limitations of the Haldane Apparatus

The Haldane burette, in which gas volumes are measured, is so constructed that the gas mixture undergoing analysis must contain approximately 75 percent of inert gas, such as nitrogen, or a similar percentage of a constituent that is not determined.

In determining combustible gases, the Haldane apparatus is limited to mixtures that do not contain combustibles in sufficient quantity to be flammable and that contain enough oxygen to burn completely all combustible gas present. Gas samples containing combustibles in amounts within or above the flammable limits must be analyzed by other means.

The Haldane apparatus is restricted, therefore, to certain types of gas mixtures, and because of its accuracy and precision is of special value in their analysis.

Principles of Gas-Volumetric Analysis as Applied in the Haldane Apparatus

The analysis of a gas mixture by the gas-volumetric method involves subjecting a measured volume of the mixture to successive treatments, each of which removes a specific constituent of the mixture. Measurement of the decreased volume caused by each such removal permits calculation of the relative proportions of the various constituents in the mixture.

In determining carbon dioxide, combustible gases, and oxygen with the Haldane apparatus this procedure is applied by measuring the gas volumes in a burette, which is essentially a graduated glass tube. Carbon dioxide is removed by passing the gas from the burette into a pipet that contains an alkaline medium, such as potassium hydroxide solution. Combustible gases are determined by passing the gas sample into a pipet containing an electrically heated platinum wire that causes these gases to burn. Carbon dioxide produced by combustion is removed by again passing the gas into the potassium hydroxide solution. Oxygen is determined by passing the gas into a pipet that contains an oxygen-absorbing medium, such as potassium pyrogallate solution. The gas sample is confined in the burette by a column of mercury, the level of which may be raised and lowered, thus forcing the gas alternately from the burette to the pipets through suitable communicating tubes. Gas volumes measured in the burette are brought to comparable conditions of temperature and pressure by a compensating device attached to the burette.

Factors that May Affect the Accuracy of Analysis

In gas-volumetric analysis certain factors must be considered if results of maximum accuracy are to be obtained. The most important of these, as related to analysis in the Haldane apparatus, are discussed in the following paragraphs.

Change of Temperature and Barometric Pressure During Analysis

As gas-volumetric analysis consists of a series of measurements of change of volume caused by removal of the various constituents of a mixture, all other factors tending to cause change of volume must be eliminated. The volume of a gas changes with temperature provided the pressure remains constant; therefore, considerable error might be introduced by variations in temperature during analysis unless correction is made for them by calculation, or they are compensated for by the design of the apparatus. Likewise correction or compensation must be made to avoid errors from changes in gas volume owing to variations in barometric pressure during analysis.

The Haldane apparatus is equipped with a device that compensates for changes in temperature or pressure, eliminating the necessity for correcting gas volumes to standard conditions by calculation. All gas volumes measured in the burette are balanced against a fixed volume of gas contained in a closed tube in a water-jacket that also surrounds the burette. Any temperature change that occurs in the apparatus during analysis produces similar effects on the gas in the burette and in the closed compensator tube, and the temperature effect is nullified or cancelled. As the gas volumes measured in the burette are balanced against a fixed volume of gas in the compensator tube, compensation for changes in barometric pressure also is obtained. The use of the compensating device is described in the instructions for operating the apparatus.

Change of Water-Vapor Content of Gas Sample During Analysis

As a volume of gas may contain varying amounts of water vapor, depending upon temperature and degree of saturation of the gas with water vapor, this condition must be controlled in gas-analysis procedures to prevent changes in gas volume by the presence of varying amounts of water vapor during analysis.

In the Haldane apparatus the gas is kept saturated with water vapor by maintaining a small amount of water in the burette at all times. If this procedure were not followed, a sample of dry or incompletely saturated gas, passed into the potassium hydroxide solution for determining carbon dioxide, would gain water vapor from the solution, and the determination would be in error by the amount of water vapor gained. A small amount of water also is maintained in the closed compensator tube, and the effect of variation in vapor-pressure of the water caused by temperature changes is nullified, as the gas in both burette and compensator tube is affected to the same extent.

Solubility of Gases in Confining Liquids

All gases are soluble to some extent in water, and if water were used as the confining liquid considerable error would be introduced through solubility. To eliminate this source of error mercury is used as the confining liquid in the burette and combustion pipet and for displacing gas from the sample container into the burette.

Solubility of Gases in Reagents

In the use of reagents such as potassium hydroxide and potassium pyrogallate solutions, physical solution of some of the constituents of the gas sample is possible, in addition to removal by chemical action of the constituent for which the reagent is specifically intended. Potassium hydroxide solution exerts no significant

solvent action on gases, such as oxygen, nitrogen, methane, carbon monoxide, and hydrogen, that may come into contact with it during the determination of carbon dioxide, and after one or two analyses are made the solubility error becomes negligible. In the case of potassium pyrogallate solution, however, there is appreciable solubility of nitrogen until the reagent has become saturated with that gas. When a fresh solution of potassium pyrogallate is used in the apparatus at least two analyses of normal air should be made before the oxygen values obtained are taken as correct. When gases and vapors such as unsaturated hydrocarbons, gasoline, and benzol are determined in the Haldane apparatus, appreciable solution of these compounds may occur if the sample is passed into the potassium hydroxide solution before combustion. In such instances a modified procedure, described later, usually will eliminate this error.

Calibration of the Burette

Burettes usually are graduated as accurately as possible by the manufacturer, but it is difficult to obtain absolute accuracy over the entire length of a burette of the small diameter used in the Haldane apparatus. Consequently, it is advisable to calibrate the burette before use. The procedure for calibrating burettes is included under Comments on Use and Maintenance of the Apparatus.

Description of Apparatus

Essential parts of the Haldane apparatus are shown in figure 6.

Burette

Burette f (See fig. 6) has a total capacity of 21 ml. The bulb at the upper part of the burette has a capacity of 15 ml. and is not divided by graduations. The capacity of the stem below the bulb is 6 ml., graduated in hundredths of a milliliter. Graduation of the burette begins at the bottom of parallel-bore stopcock e. This stopcock may be turned to communicate through stopcock d and capillary glass tubing c to the sample container, a, or may be rotated from this position through 180 degrees to communicate with the pipets, l, m, and n, through the capillary glass manifold and stopcocks i, j, and k. The burette is enclosed in a water jacket, g, to protect it from sudden temperature changes. A tube connected to a compressed-air supply extends nearly to the bottom of the water jacket, and a stream of air bubbles escaping from this tube produces circulation and uniformity of temperature of the water throughout the jacket. The lower end of the burette is connected by heavy-walled rubber tubing to a leveling bulb, s, which rests in a movable support, t.

Air-Lift for Mercury in Burette

The tedium of repeated manual raising and lowering of the leveling bulb, s, required to pass the gas sample into and to withdraw it from the various pipets, l, m, and n, may be relieved considerably by use of the air-lift device[15] shown in figure 6.

Compressed air at 6 to 6.5 pounds p.s.i.g. may be admitted through a specially designed brass stopcock to a flexible rubber or plastic tube communicating with and fitting tightly into the upper opening of the leveling bulb, s. When gas sample is passed into a pipet, the leveling bulb, s, is raised approximately to the position shown in figure 6 and until the mercury level in the burette, f, is approximately

15/ Designed by Albert Rhode, of the Gas Analysis Laboratory, Branch of Health Research, Bureau of Mines, Pittsburgh, Pa.

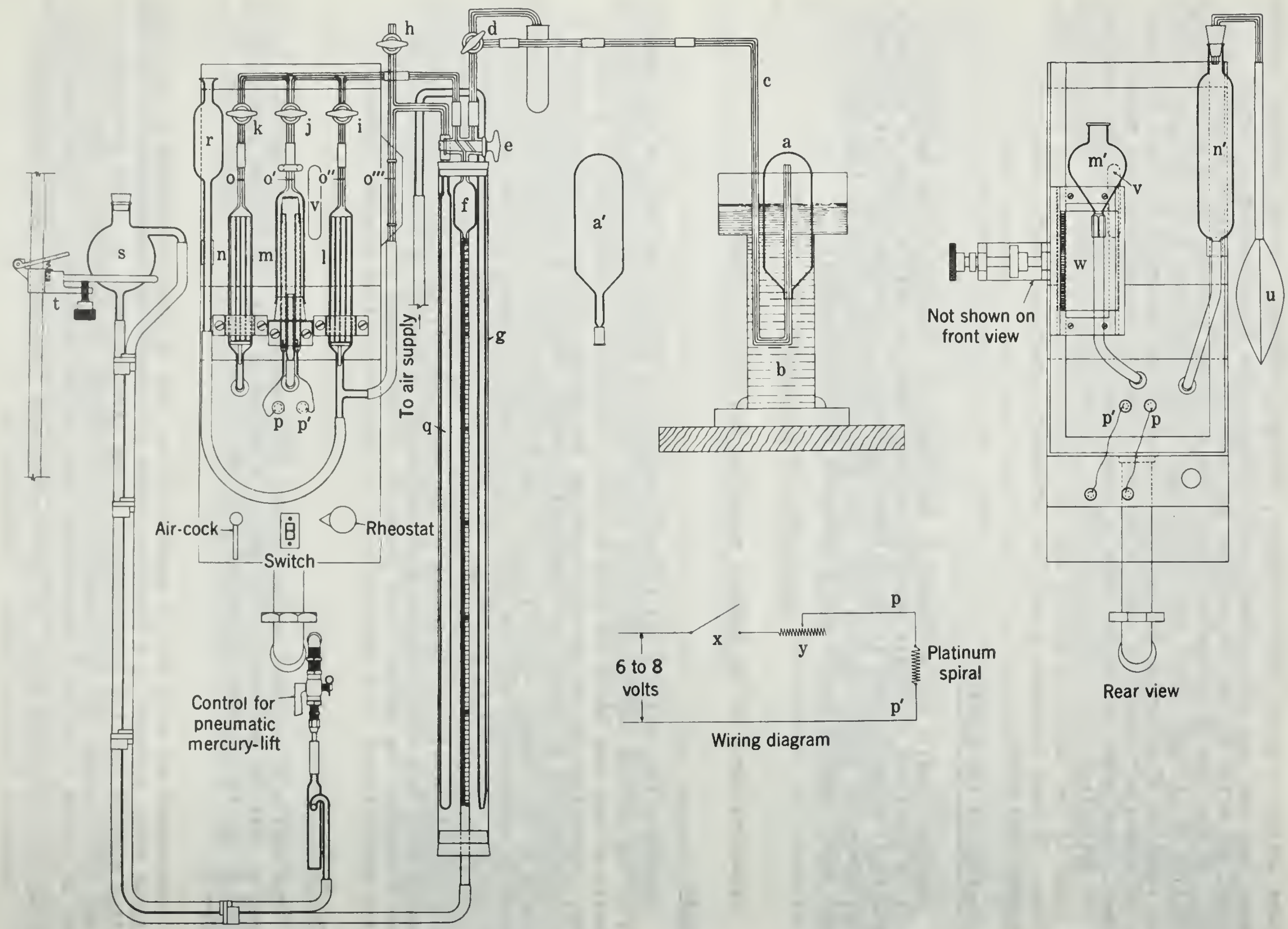

Figure 6. - Diagrammatic sketch of Bureau of Mines Haldane gas-analysis apparatus.

at 15.4 ml., the brass control stopcock is opened applying air pressure to the mercury in s, forcing it downward, and causing the mercury in the burette, f, to rise and fill the bulb at the top of the burette, thus forcing the gas sample into the pipet in use. When the desired limit of motion of the mercury has been reached, the brass stopcock is turned through 90 degrees, closing off the compressed air supply and allowing the air compressed in the leveling bulb, s, and the flexible tubing to escape to the atmosphere through a passageway drilled in the brass control stopcock in such manner that the plug of the stopcock is converted to a T-bore. This procedure allows the mercury in the bulb of the burette to descend to its original level and withdraw most of the gas sample from the pipet. Thus, the gas sample may be passed back and forth repeatedly between the burette and any one of the pipets merely by turning the handle of the brass control stopcock back and forth through 90 degrees.

The analyst can return to manual operation of the leveling bulb, s, as for final manipulation of reagents in the pipets or for making fine adjustments, at any time throughout the analytical procedure by placing the brass control stopcock in the closed position.

Pipets

Pipet l is for the potassium hydroxide solution used in determining carbon dioxide. The lower outlet of this pipet communicates through rubber tubing connections with reservoir r and capillary glass tube o''', which is part of the compensating device. Reservoir r is adjustable vertically.

Combustion pipet m contains a spiral of No. 26 or 28 B. & S. gage platinum wire, which is heated electrically to burn combustible gases. Mercury is used as the confining liquid in this pipet. Two glass tubes support the spiral and are filled with mercury to serve as conductors for the electric current. The upper ends of these tubes are open, and each tube has a short stud of No. 20 B. & S. gage platinum wire sealed to the glass in a vertical position at the opening. These studs furnish electrical contact between the mercury and the spiral, which is held in place by winding its ends around the studs. The lower ends of the tubes are sealed closed around two short lengths of No. 20 B. & S. gage platinum wire, to which are attached wires p and p' connecting to the electrical supply.

Pipet m is connected by rubber tubing to reservoir m', which is mounted on a slide movable vertically by a rack and pinion gear, w, attached to the reverse side of the apparatus. Reservoir m' is mounted in this manner so that it may be lowered and raised as gas is passed into and withdrawn from pipet m, keeping the mercury at approximately the same levels in m and m', thus maintaining the gas in m at approximately atmospheric pressure, thereby reducing the possibility of leakage owing to excessive pressures on the rubber tubing. The level of the mercury in reservoir m' may be observed through slot v in the panel on which the apparatus is mounted.

Pipet n contains the potassium pyrogallate solution used in determining oxygen. The lower outlet of this pipet is connected to reservoir n', the top outlet of which is connected to a rubber bag, u, that protects the reagent from the oxygen of the air.

Pipets l and n contain a number of lengths of small-diameter shell tubing, which, when gas is passed into the pipets, presents a considerable surface wet with reagent, accelerating absorption of gas. The tubes are supported at their lower ends by a helix of glass rod perpendicular to the longitudinal axes of the tubes.

Compensator

Closed tube q of the compensating device is shown in the water jacket, g. The upper end of this tube is connected through capillary glass tubing to tube o'''. Stopcock h is used to bring the pressure in the closed tube to atmospheric before beginning an analysis.

Connections to Gas Sample

The gas sample bottle, a, shown in mercury jar b, is the vacuum type used by the Bureau of Mines in sampling mine atmospheres. A sealed sample bottle is shown at a'. With bottles of this type the gas sample is transferred to the burette through U-tube c. If other types of sample bottles are used, for example those having stopcocks at both ends, c may be replaced by a short elbow of capillary glass tubing.

Electrical Accessories

Electrical accessories used in conjunction with the combustion pipet are indicated in the wiring diagram shown in figure 6. A current supply at 6 to 8 volts is necessary. Variable resistance y may be a rheostat of the carbon pile type used for radio-tube filament control, a wire-wound rheostat of sufficient capacity to prevent overheating, or a length of wire having a resistance of 1 to 2 ohms and equipped with a movable contact. Where alternating current is available, a step-down transformer furnishing current at 6 to 8 volts may be used as the power supply. The capacity of the transformer should be at least 150 watts. Where only direct current is available a lamp bank or other suitable resistance may be used. Storage batteries or dry cells may be employed but are not particularly satisfactory, as storage batteries require frequent recharging and dry cells are rapidly depleted at the rate of current consumption required.

Preparation of Solutions

Potassium Hydroxide

The potassium hydroxide solution used for determining carbon dioxide is prepared by dissolving 300 grams of potassium hydroxide in 1,000 ml. of water. Although potassium hydroxide is preferable, a solution of 200 grams of sodium hydroxide in 1,000 ml. of water also can be used. There is greater tendency, however, toward the deposition of bicarbonate with sodium hydroxide than with potassium hydroxide.

Potassium Pyrogallate

The potassium pyrogallate solution used for determination of oxygen is prepared as follows: Dissolve 50 grams of pyrogallic acid in 150 ml. of water and dissolve 1,200 grams of potassium hydroxide in 800 ml. of water. When the potassium hydroxide solution has cooled, measure 250 ml. of the solution into each of a number of bottles of approximately 325 ml. capacity, such as magnesium citrate bottles. Add 45 ml. of the pyrogallic acid solution to each bottle, close immediately, and mix. Several small bottles are preferable to one large one, as only a small portion of the solution is exposed to the oxygen of the air when the bottle is opened, whereas if stored in a single large container all the solution will be exposed each time the container is opened.

Preparation of Apparatus for Use

Assembling Burette

Burette f (fig. 6) is filled by adding clean (preferably distilled) mercury through the leveling bulb, s, with stopcock e open. Mercury is added until, with s raised so that the mercury rises to stopcock e, only a few milliliters of mercury remain in s.

Two or three milliliters of water are added to the compensator tube, q, before it is inserted in the water jacket. Tubes q and o''' are connected by rubber tubing as shown, and the water jacket is filled with water. Stopcock e is connected to the manifold and to stopcock d and U-tube c by rubber tubing.

Making Rubber Tubing Connections

It is important that rubber tubing of the proper type and size be used in making connections between the various parts of the apparatus. Seamless tubing of the pure-gum type is satisfactory, as it adheres to glass, forming a gastight joint. The inside diameter of the tubing should be such that it makes a snug fit with the glass. For example, rubber tubing of 5 mm. inside diameter should be used to join glass tubes of 7 mm. outside diameter. Rubber tubing connections should be 1-1/4 to 1-1/2 inches in length so that the rubber extends 5/8 to 3/4 inch on each side of the junction of the glass tubes. Fitting the rubber tubing over the glass is facilitated by moistening the interior of the rubber and forcing it onto the glass with a reciprocating rotary motion. The ends of the glass tubes should fit closely together to make as nearly as possible a glass-to-glass joint.

Addition of Water to Burette

When the burette has been assembled, 2 or 3 ml. of distilled water are drawn into the burette through d and the leveling bulb, s, is lowered until the mercury in the burette reaches the 21 ml. mark. Bulb s then is raised until mercury is discharged from the outlet of d. This procedure leaves a film of water adhering to the inside surface of the burette. As previously discussed, this film of water must be present at all times during analysis to saturate the gas in the burette with water vapor.

Filling Pipets

The rubber tubing connections between pipet l, tube o''', and reservoir r are installed next. Sulfur-free tubing of 6 to 8 mm. inside diameter is used. Sulfur-free rubber is used, as the action of potassium hydroxide solution on rubber containing sulfur in time will produce a substance that absorbs oxygen, and carbon dioxide determinations will be in error owing to the absorption of oxygen in addition to carbon dioxide.

The pipets, l, m, and n, are connected next to stopcocks i, j, and k by rubber tubing.

Pipet l is filled by adding potassium hydroxide solution to reservoir r, with the plug of stopcock i removed and stopcock h open. The position of r and the amount of solution added are regulated so that when the level of the solution in l rises to point o'' the bulb of r contains only a few milliliters of solution. If an excessive amount of solution is added, r may overflow when gas is introduced into

pipet l. This precaution applies also to filling reservoirs n' and m'. When l is filled the plug of stopcock i is replaced.

Pipet n is filled by adding potassium pyrogallate to reservoir n' with the plug of stopcock k removed until the solution rises to point o. The plug of stopcock k is replaced and rubber bag u is partly inflated and inserted in the opening of n', as shown.

Combustion pipet m is filled by adding clean (preferably distilled) mercury to reservoir m', with plug of stopcock j removed, until the mercury rises to point o'. The plug of stopcock j is replaced when m is filled. The glass tubes that support the platinum spiral must be filled completely with mercury. This may be accomplished by adjusting the position of m' so the mercury level in m is just at the tops of the glass tubes and then tapping the pipet so that small globules of mercury drop into the tubes until they are filled. An alternate procedure is to remove the rubber stopper (before mercury is added to the pipet) that supports the tubes and to fill them with mercury through a funnel with a small-diameter stem. When the stopper is reinserted in the pipet it should be moistened and pressed firmly into place to insure a gastight fit.

Adjusting Temperature of Platinum Spiral

When m has been filled the electric connections are attached, the mercury level is lowered until the spiral is exposed, and switch x is closed. The temperature of the spiral is adjusted by rheostat y so that the wire is at a bright yellow heat. It is important to heat the spiral to a temperature that will completely burn the combustible gases but not to the extent of fusing the wire. Switch x is opened after the temperature of the spiral has been adjusted properly.

Greasing Stopcocks

All stopcocks are cleaned and greased. Greasing the stopcocks properly is an important part of the analytical procedure. Improper greasing is likely to cause errors in analysis and difficulties in manipulating the apparatus. Stopcock lubricants suitable for use with the Haldane apparatus are available from laboratory supply houses. Usually it is preferable to purchase these ready-made lubricants rather than to undertake the preparation of a suitable lubricant in the laboratory.

The plug and barrel of the stopcock are cleansed by wiping with cheesecloth. The barrel may be cleaned by wrapping two or three layers of cheesecloth over the end of a pencil and passing this through the barrel with a rotary motion. The capillary openings may be cleaned with a pipe cleaner or soft copper wire. Instruments that might scratch the ground surface of the stopcock should not be used. The stopcock is lubricated by placing a thin layer of grease, extending the length of the plug, along the sides of the plug not pierced by the bore. The plug is inserted in the barrel, pressed firmly into place, and rotated several times in both directions. If greased properly, an even, transparent film of grease covers the ground surfaces of the stopcock at all points of contact. Application of the proper amount of grease is a skill learned best by experience. If too little grease is applied, striations and bubbles will be evident, and the stopcock may leak. If an excess of grease is used the bore will become plugged in a short time, impeding or stopping flow of gas through the stopcock. Stopcock plugs often are not interchangeable, and it is best to remove only one plug at a time to avoid confusion.

Adjusting Levels of Liquids in Pipets

The solutions in pipets l and n and the mercury in pipet m are brought to o, and o'', by drawing about 20 ml. of air into the burette and turning stopcock e to communicate with the manifold. Stopcock i is opened and the level of the solution is adjusted to mark o'' by raising or lowering leveling bulb s as necessary. This procedure, from the opening of stopcock i, must be conducted with care, as the caustic solution in l may easily be drawn into the manifold and possibly into the burette. If this should occur all parts accidentally brought into contact with caustic solution must be cleaned thoroughly with dilute sulfuric acid.

The same procedure is used in bringing the liquids in pipets n and m to marks o and o'. The precautions regarding manipulation of the caustic solution apply in adjusting the potassium pyrogallate solution in n to mark o.

Testing for Leaks

The apparatus is next tested for leaks. Stopcocks e and d are turned to communicate with the atmosphere, and the leveling-bulb, s, is lowered until about 20 ml. of air has been drawn into the burette. Stopcock e is then closed, and s is raised to the top of its supporting rod. A gradual rise in the level of mercury in the burette indicates a leak at stopcock e. If the mercury level remains stationary, turn e to communicate with the manifold. A gradual rise in mercury level in the burette indicates leakage at stopcocks i, j, or k or at the rubber tubing connections between e and the manifold. Leakage at i, j, or k usually, but not always, causes the solutions to drop from marks o, o', and o''. If no leaks are indicated, the rubber tubing connections below i, j, and k are tested next. Reservoirs n' and m' are lowered as far as possible and maintained in that position for several minutes. If no leaks are present in the rubber tubing connections below stopcocks k and j, the liquids in pipets n and m will return to marks o and o' when n' and m' are returned to their former positions. With stopcock h open, reservoir r is adjusted so that the solution in the compensator tube coincides with mark o'''. (If the level of the solution in l does not coincide with o'' it should be brought to that mark by opening i, adjusting the leveling-bulb, s, and closing i.) Stopcock h is closed and r lowered as far as possible for several minutes. If a leak exists in the rubber connection below stopcock i, the solution will fail to return to o'' when r is returned to its former position; if the solution fails to return to mark o''', a leak exists in h or in the rubber connection with closed tube q.

Leaks at stopcocks may be corrected by regreasing or, if this fails, by regrinding (see Comments on Use and Maintenance of Apparatus) and regreasing. Leaks at rubber tubing connections may be corrected by replacing the tubing; if the tubing that leaked did not appear to fit tightly to the glass, it should be replaced by tubing of smaller inside diameter, or the joint between glass and rubber may be improved by wrapping the rubber connection, at about one-quarter inch from each end, with two strands of No. 22 copper wire, twisting the free ends of the wire together after wrapping.

Stopcock d and rubber connections to U-tube c are tested for leaks by turning d to communicate with c, raising the leveling-bulb, s, until the mercury in the burette, f, rises to stopcock e, closing the outlet of c by placing a finger over the open end of the tube, and lowering s. If the mercury level in f continues to fall, a leak is indicated between e and c.

Analytical Procedure

Filling Manifold With Nitrogen

After the apparatus has been assembled and tested for leaks, the first step in the analytical procedure is to fill the manifold from stopcock e to marks o, o', and o'' with nitrogen. As the manifold is not purged by the mercury in the burette when a sample is drawn into the apparatus, its volume is "dead space" and must be filled with a gas that is inert with respect to the various treatments to which the gas sample is subjected. To fill the manifold with nitrogen, 20 ml. of air is drawn into the burette through stopcocks e and d; e is turned to communicate with the manifold, stopcock k is opened, and the air sample in the burette, f, is passed back and forth between f and pipet n by raising and lowering the leveling bulb, s. Ten to twelve passes usually are sufficient to absorb the oxygen from the air sample. (As an aid in determining when the oxygen has been absorbed, the color of the potassium pyrogallate solution adhering to the tubes in the pipet may be observed. While oxygen is being absorbed the film of reagent on these tubes becomes brownish-red. When the oxygen has been absorbed the reagent assumes a greenish hue. Four or five additional passes should be made after the red no longer can be observed.) After the oxygen has been absorbed, the residual nitrogen[16] is withdrawn from n to the burette, f, and k is closed. The gas then is passed once into pipets m and l to remove the oxygen present in the capillaries below stopcocks i and j. When the gas is withdrawn from these pipets the liquids in the pipets are adjusted to marks o' and o'', and i and j are closed. The gas is again passed six times into n to remove the oxygen picked up in the capillaries below i and j. When this has been done the gas is returned to f, the liquid in n is brought to mark o, and k is closed.

Stopcocks i and h are opened and the level of the potassium hydroxide solution adjusted to marks o'' and o'''. Stopcocks i and h then are closed, and stopcock e is rotated 180 degrees. This procedure leaves the manifold filled with nitrogen at "compensated pressure" and brings the air in the closed tube of the compensator to atmospheric pressure. Stopcock h must not be opened during an analysis, but may be opened between analyses to reestablish atmospheric pressure in the closed tube of the compensator and should be left open when the apparatus is not in use.

Drawing Sample Into Burette

Stopcocks e and d are turned to communicate with U-tube c, and the leveling bulb, s, is raised until mercury flows from the outlet of c. Stopcock e is then turned 90 degrees.

If the gas to be analyzed is contained in a vacuum-type sample bottle, as shown in figure 6, a file mark is made on the neck of the bottle, the neck is placed under mercury in jar b, and broken off by tapping against the side of the jar. The open end of the sample bottle is kept beneath the mercury, and c is inserted as shown in figure 6. If the sample is contained in a tube having stopcocks at both ends, c is replaced by a short elbow of capillary tubing. One stopcock of the sample tube is attached to the outlet of this elbow by rubber tubing and the other submerged in the mercury in jar b before opening.

16/ As the potassium pyrogallate solution is alkaline, the carbon dioxide of the air is removed along with the oxygen. The residual nitrogen of the air contains about 1 percent of the "noble gases" (argon, neon, xenon, krypton, and helium), which are inert and which, in ordinary gas analysis, are included in the term "nitrogen."

After the sample tube has been connected s is lowered, e is turned to communicate with the sample, and 18 to 20 ml. of sample is drawn into the burette, f. Stopcock d then is turned to communicate with the atmosphere, and s is raised until mercury flows from the outlet of d to discharge bubbles of air that may have been trapped in the capillary between U-tube c and stopcock e. Stopcock d is turned to communicate with the sample, and s is lowered until approximately 20 ml. of sample has been drawn into f. The position of the sample tube is adjusted so that the levels of the mercury inside and outside the sample tube coincide, and e is turned to communicate with the manifold.

Reading Burette

Stopcock i is opened cautiously (the level of the solution in pipet l should not move very far in either direction from mark o'') and the positions of leveling-bulb s and reservoir r so adjusted that the solution in l is at mark o'' and that in the compensator tube at mark o'''. The volume of gas sample in the burette, f, is then read to the nearest 0.002 ml. (with stopcock i open), which gives the volume of sample taken for analysis.

The "compensating" procedure described in the foregoing paragraph - that is, the adjustment of the level of the potassium hydroxide solution to marks o'' and o''' - is followed throughout the analysis before each volume reading in the burette is made.

Determining Carbon Dioxide

Carbon dioxide is removed from the sample by raising and lowering the leveling-bulb, s, with stopcock i open, causing the gas to pass back and forth between burette f and pipet l. After six passes into l the gas is withdrawn to f, the level of the potassium hydroxide solution adjusted to marks o'' and o''', as previously described, and the burette reading taken. It is well to check this reading, until technique is perfected, by passing the gas into l six more times and again reading the burette. After the burette is read, stopcock i is closed. The burette reading is subtracted from the original volume of sample to obtain the volume of carbon dioxide in the sample. The percentage of carbon dioxide in the sample is calculated as follows:

$$\text{Percent, by volume,}^{17/} \text{ of carbon dioxide} = \frac{\text{volume of carbon dioxide}}{\text{original volume of sample}} \times 100$$

Determining Combustible Gases

Combustible gases are determined by opening stopcock j and passing the gas into pipet m, lowering reservoir m' at the same time so that the mercury levels in m and m' coincide. When the platinum spiral is exposed, switch x is closed. (The Haldane apparatus is not designed for determining combustible gas-air mixtures within the flammable range. If an attempt is made to burn a flammable mixture in pipet m, an explosion may result. If there is doubt as to the amount of combustible in the sample, a piece of wire screen or shatter-proof glass should be placed in front of the pipet to protect the operator.) To cool the pipet a stream of air is directed over it by a curved glass or metal tube (shown surrounding the capillary outlet of m

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17/ The results of gas-volumetric analysis are reported as percent by volume rather than percent by weight. The results usually are reported on a dry basis, that is, account is not taken of the water-vapor content of the sample.

in fig. 6) pierced on the lower side by a number of small holes. If the temperature of the platinum spiral has not been adjusted previously it should now be adjusted to the proper temperature. (See Preparation of Apparatus for Use.) The gas is passed back and forth between the burette, f, and pipet m 8 to 10 times, keeping the mercury in m and m' at the same level. Switch x is opened, and the pipet is allowed to cool to room temperature. The gas is withdrawn to f, the mercury in m brought to mark o', and stopcock j closed. Stopcock i is opened, the level of the potassium hydroxide solution brought to marks o'' and o''', and the burette reading taken. This reading subtracted from that obtained after removal of the carbon dioxide gives the contraction in volume owing to combustion.

Carbon dioxide produced by combustion is determined by passing the gas six times into l, compensating, and reading the burette. If the contraction owing to combustion exceeds 0.200 ml., the sample should be subjected to combustion a second time and the carbon dioxide produced by the second combustion determined. The two contractions and the two carbon dioxide values are added to obtain the total contraction in volume and the total carbon dioxide produced by combustion. If methane is the only combustible gas in the sample, the percentage of methane is calculated from these values as follows:

$$\text{Volume of methane in sample} = \frac{\text{contraction caused by combustion + carbon dioxide formed}}{3}$$

$$\text{Percent, by volume, of methane} = \frac{\text{volume of methane}}{\text{original volume of sample}} \times 100$$

Methods for calculating the volumes of combustible gases other than methane and of various combinations of combustible gases are given in the section on Calculating Results.

Determining Oxygen

Oxygen is removed from the sample by passing the gas into the potassium pyrogallate solution in pipet n. The gas is passed 12 times (this number of passes usually suffices but it is advisable to observe the color change in the solution, as previously mentioned) into pipet n and then is withdrawn to the burette, f, stopcock k is closed, and the gas is passed once into pipets m and l to pick up oxygen remaining in the capillaries below stopcocks j and i. The gas is then passed six times more into n and withdrawn to f, the level of the solution in n being adjusted to mark o before k is closed. The volume of gas in the burette is compensated and the burette reading taken. It is well to check this reading by passing the gas again into n four or five times and taking a second burette reading. This reading, subtracted from the reading obtained after the final removal of carbon dioxide produced by combustion, gives the volume of oxygen remaining in the sample after combustion. If the sample contains combustible gas, a definite volume of oxygen has been consumed in the combustion, and this volume of oxygen must be calculated and added to the volume of oxygen determined by absorption to obtain the total volume of oxygen in the sample.

If methane is the only combustible gas in the sample the calculation is as follows:

Volume of oxygen consumed in combustion = 2 x volume of methane.

Total volume of oxygen in sample = volume of oxygen determined by absorption + volume of oxygen consumed in combustion.

$$\text{Percent, by volume, of oxygen} = \frac{\text{total volume of oxygen}}{\text{original volume of sample}} \times 100$$

Calculation of oxygen consumed in combustion of various gases is illustrated in the section on Calculating Results.

Determining Nitrogen

The percentage of nitrogen is obtained by subtracting the sum of the percentages of the other constituents from 100:

Percent, by volume, of nitrogen = 100 - (percent carbon dioxide + percent combustible gas + percent oxygen).

Calculating Results

In the preceding section, Analytical Procedure, the volume of methane in the sample was calculated by adding the contraction in volume and the carbon dioxide produced by combustion and dividing this sum by three. This calculation is based on the volume relations expressed by the reaction

$$CH_4 + 2\ O_2 = CO_2 + 2\ H_2O$$

One volume[18] of methane requires 2 volumes of oxygen for complete combustion, and 1 volume of carbon dioxide and 2 volumes of water vapor are formed. As the water vapor condenses and occupies negligible space, the carbon dioxide is the only measurable product of combustion. Therefore, 3 volumes of gas are reduced to 1 volume by combustion. In other words, the contraction produced by combustion of 1 volume of methane is twice the volume of the methane, and the carbon dioxide produced is equal to the volume of the methane, as shown in the following equations:

$$\text{Contraction} = 2 \times CH_4$$

$$\text{Carbon dioxide} = CH_4$$

Combining and solving these equations,

$$\text{Methane} = \frac{\text{contraction} + CO_2}{3}$$

Formulas for calculating the volume of any single combustible gas may be derived in the same manner. For example, from the reaction

$$2\ CO + O_2 = 2\ CO_2$$

18/ The term "volume" means any unit volume, as milliliter, cubic inch, cubic foot, etc.

$$\text{Carbon monoxide}^{19/} = 2/3\ (\text{contraction} + CO_2)$$

and from the reaction.

$$2\,H_2 + O_2 = 2\,H_2O$$

$$\text{Hydrogen} = 2/3\ \text{contraction}$$

These reactions indicate also that carbon monoxide and hydrogen require one-half their volume of oxygen for complete combustion.

The following example illustrates data relating to analysis of a sample of coal-mine air containing carbon dioxide, methane, oxygen, and nitrogen.

Analytical Data

	Burette reading, ml.	Difference, ml.
Volume of sample taken for analysis	20.010	
Volume after carbon dioxide absorption	19.978	
Contraction owing to carbon dioxide absorption		0.032
Volume after combustion	19.922	
Contraction owing to combustion		.056
Volume after carbon dioxide absorption	19.894	
Carbon dioxide owing to combustion		.028
Volume after absorption of residual oxygen	15.820	
Residual oxygen		4.074
Oxygen consumed in combustion of methane		.056
Total oxygen		4.130

Calculations

	Percent by volume
Carbon dioxide $\frac{0.032}{20.010} \times 100$	0.16

19/ If a sample is suspected of containing carbon monoxide in amounts at, or near, the limit of accuracy of the Haldane apparatus, the gas-volumetric analysis should be supplemented by tests specific for carbon monoxide, such as the pyrotannic acid method, to verify the presence or absence of this gas. See Sayers, R. R., and Yant, W. P., The Pyrotannic Acid Method for the Quantitative Determination of Carbon Monoxide in Blood and in Air: Tech. Paper 373, Bureau of Mines, 1925, 18 pp.

When carbon monoxide is known to be present, concentrations of 0.1 percent or more may be determined with a modification of the Haldane-type apparatus. See Berger, L. B., Determination of Carbon Monoxide by Absorption in the Haldane-Type Gas Analysis Apparatus: Bureau of Mines Rept. of Investigations 4187, 1947, 6 pp.

Concentrations of carbon monoxide less than 0.1 percent may be determined colorimetrically by use of a special reagent. See Polis, B. D., Berger, L. B., and Schrenk, H. H., Colorimetric Determination of Low Concentrations of Carbon Monoxide by Use of a Palladium Chloride-Phosphomolybdic Acid-Acetone Reagent: Bureau of Mines Rept. of Investigations 3785, 1944, 13 pp.

Calculations (Con.)

	Percent by volume
Methane $\frac{0.056 + 0.028}{3} = 0.028$	
$\frac{0.028}{20.010} \times 100$	0.14
Oxygen $(2 \times 0.028) + 4.074 = 4.130$	
$\frac{4.130}{20.010} \times 100$	20.64
Nitrogen (by difference) $100 - (0.16 + 0.14 + 20.64)$	79.06

The volume of each gas in mixtures containing any two of the gases methane, carbon monoxide, and hydrogen may be calculated from contraction and carbon dioxide produced by combustion. The calculations are based on the following reactions:

$$CH_4 + 2\ O_2 = CO_2 + 2\ H_2O \qquad (1)$$

$$2\ CO + O_2 = 2\ CO_2 \qquad (2)$$

$$2\ H_2 + O_2 = 2\ H_2O \qquad (3)$$

Methane and carbon monoxide. - When the mixture contains methane and carbon monoxide the following relations are obtained from equations (1) and (2):

$$\text{Contraction} = 2 \times CH_4 + 1/2\ CO \qquad (4)$$

$$\text{Carbon dioxide} = CH_4 + CO \qquad (5)$$

Solving equations (4) and (5),

$$\text{Methane} = \frac{2 \times \text{contraction} - CO_2}{3}$$

$$\text{Carbon monoxide} = CO_2 - CH_4$$

Methane and hydrogen. - When the mixture contains methane and hydrogen the following relations are obtained in like manner from equations (1) and (3):

$$\text{Methane} = CO_2$$

$$\text{Hydrogen} = \frac{2 \times \text{contraction} - 4 \times CO_2}{3}$$

Hydrogen and carbon monoxide. - When the mixture contains hydrogen and carbon monoxide the following relations are obtained from equations (2) and (3):

$$\text{Hydrogen} = \frac{2 \times \text{contraction} - CO_2}{3}$$

$$\text{Carbon monoxide} = CO_2$$

Methane, carbon monoxide, and hydrogen. - When the mixture contains methane, carbon monoxide, and hydrogen, the volume of oxygen consumed by combustion must be determined in addition to the contraction and carbon dioxide produced by combustion to calculate the volume of each gas. The volume of oxygen consumed is determined by subjecting one portion of the sample to the complete procedure - determining carbon dioxide, contraction owing to combustion, carbon dioxide produced by combustion, and residual oxygen remaining after combustion - and analyzing a second portion of the sample for carbon dioxide and oxygen only. The oxygen consumed by combustion in the first portion is calculated as follows:

First portion (A). - Carbon dioxide, contraction and carbon dioxide produced by combustion and residual oxygen determined.

Second portion (B). - Carbon dioxide and oxygen determined.

$$\text{Percent oxygen in B} = \frac{\text{volume of oxygen determined}}{\text{original volume of sample}} \times 100$$

$$\text{Total volume oxygen in A} = \frac{\text{original volume of A} \times \text{percent oxygen in B}}{100}$$

Volume oxygen consumed in combustion of A = total volume oxygen in A - volume residual oxygen in A.

From equations (1), (2), and (3), the following relations are obtained:

$$\text{Hydrogen} = \text{contraction} - \text{oxygen consumed},$$

$$\text{Methane} = \frac{(2 \times \text{contraction} - CO_2)}{3} - H_2$$

$$\text{Carbon monoxide} = CO_2 - CH_4$$

When two or more gases are determined by combustion the small, unavoidable errors of analysis may be cumulative in random instances and in such instances may be multiplied in the calculations, reducing to some extent the accuracy and precision of determinations of these gases.

A typical analysis of a sample containing carbon dioxide, hydrogen, methane, carbon monoxide, oxygen, and nitrogen follows:

First portion. -

	Burette reading, ml.	Difference, ml.
Volume of sample taken for analysis	20.430	
Volume after carbon dioxide absorption	20.185	
Contraction owing to carbon dioxide absorption		0.245
Volume after combustion	20.002	
Contraction owing to combustion		.183
Volume after carbon dioxide absorption	19.882	
Carbon dioxide owing to combustion		.120
Volume after oxygen absorption	16.180	
Residual oxygen		3.702

Second portion. -

Volume of sample taken for analysis	20.270	
Volume after carbon dioxide absorption	20.025	
Contraction owing to carbon dioxide		.245
Volume after oxygen absorption	16.205	
Contraction owing to oxygen absorption		3.820

Calculations.- From analysis of the second portion the oxygen content of the sample is $\frac{3.820}{20.270} \times 100$, or 18.85 percent by volume.

Total volume of oxygen in first portion =

$$\frac{20.430 \times 18.85}{100} = 3.851 \text{ ml.}$$

Volume oxygen consumed in combustion of first portion =
3.851 - 3.702 (residual oxygen of first portion) = 0.149 ml.

Volume hydrogen in first portion = contraction - oxygen consumed =
0.183 - 0.149 = 0.034 ml.

Volume methane in first portion = $\frac{2 \times \text{contraction} - CO_2}{3} - H_2$ =
$\frac{0.366 - 0.120}{3} - 0.034 = 0.048$ ml.

Volume carbon monoxide in first portion = $CO_2 - CH_4$ = 0.120 - 0.048 =
0.072 ml.

Results of analysis. -

	Percent by volume
Oxygen = $\frac{3.820}{20.270} \times 100$ (from analysis of second portion) =	18.85
Carbon dioxide = $\frac{0.245}{20.430} \times 100$ (from analysis first portion) =	1.20

Results of analysis (Con.)

	Percent by volume
Hydrogen = $\frac{0.034}{20.430}$ x 100 (from analysis first portion) =	0.17
Methane = $\frac{0.048}{20.430}$ x 100 (from analysis first portion) =	.23
Carbon monoxide = $\frac{0.072}{20.430}$ x 100 (from analysis first portion) =	.35
Nitrogen (by difference) = 100 - (18.85 + 1.20 + 0.17 + 0.23 + 0.35) =	79.20

Hydrocarbon-air mixtures. - Saturated hydrocarbons of the formula C_nH_{2n+2}, such as natural gas and gasoline vapor, may be calculated from the following equation:

$$\text{Volume of hydrocarbons} = \frac{2 \times \text{contraction} - CO_2}{3}$$

If the combustible consists mainly of higher hydrocarbons, as "wet" natural gas or gasoline vapor, it is advisable to determine only contraction and carbon dioxide produced by combustion, as these higher hydrocarbons are appreciably soluble in the potassium hydroxide solution, and if the sample is passed first into this solution to determine carbon dioxide, error may be introduced through solubility. If the sample consists of hydrocarbons and normal air, correction may be applied to the combustion data for the carbon dioxide content of the air (0.03 percent).

Comments on Use and Maintenance of Haldane Apparatus

Location of Apparatus

The Haldane apparatus should be installed in a location free from drafts and not subject to wide variations or sudden changes in temperature. Sudden changes in temperature during an analysis may cause the level of the liquid in the compensating tube to move beyond the working range of the apparatus.

Calibration of Burette

The burette is calibrated while in the water jacket, which is filled with water and maintained at as nearly constant temperature as possible. A thermometer inserted in the water jacket indicates the temperature. A two-way stopcock is sealed to the lower end of the burette, mercury is introduced into the burette through a leveling-bulb and rubber tubing attached to one outlet of this stopcock, and mercury is added until it reaches the bottom of the stopcock at the upper end of the burette. Successive portions of mercury are withdrawn through the open outlet of the lower stopcock and weighed. The burette reading is noted after each portion is withdrawn. The true volume of each portion is calculated from its weight and observed temperature.

Precautions Against Contamination of Apparatus by Caustic Solutions

It is of utmost importance to keep the stopcocks, manifold, combustion pipet, and burette free of the slightest traces of potassium hydroxide or potassium pyrogallate solutions if accurate analyses are to be obtained. Even though the

solutions have not been observed to enter these parts of the apparatus, it is advisable to cleanse them if the results of analysis seem doubtful and no other cause of error is evident. The mercury used in displacing the sample from its container and all connections to the sample container also must be kept free of caustic.

Cleaning Manifold

The preferred method of cleaning the manifold is to remove it from the apparatus and draw through it, in the order named, dilute sulfuric acid, distilled water, and air.

Cleaning Burette

The burette may be cleaned by a mixture of equal parts of concentrated sulfuric acid and saturated potassium dichromate solution. An alternate procedure is to draw into the burette a solution of 90 percent concentrated nitric acid and 10 percent water, allow it to remain for a few minutes, and then discharge it. A solution containing 50 percent concentrated nitric acid is used next, followed by solutions containing 25 and 5 percent concentrated nitric acid, and finally the burette is washed several times with distilled water. This may be done without draining the mercury from the system, as the gradual decrease in acid concentration prevents deposition of mercurous nitrate on the walls of the burette.

Organic solvents should not be used to clean any part of the apparatus.

Grinding Stopcocks

If stopcocks are unsatisfactory owing to poor fit between plug and barrel or if they become eroded by wear or the action of caustic solutions, they may be reground by the following procedure: The plug of the stopcock is given a thin coating of moistened abrasive (400 to 600-mesh), inserted in the barrel lightly, and turned with a reciprocating rotary motion. The plug is withdrawn from the barrel after each four or five turns to prevent formation of grooves in the ground surfaces. At intervals the stopcock is washed free of abrasive, dried, and greased. When an even, transparent film of grease is obtained between plug and barrel at all points of contact, grinding is complete. (If the stopcock is deeply eroded, so much grinding may be necessary that the capillary bores are thrown out of alinement and the stopcock becomes useless.)

Analysis of Normal Air to Check Analytical Procedure

Technique of operation and condition of apparatus may be considered satisfactory when the results obtained in analysis of normal air are in agreement with its actual composition (0.03 percent carbon dioxide, 20.95 percent oxygen, 0.00 percent combustible, and 79.02 percent nitrogen).

Difficulties Encountered in Using Haldane Apparatus

In the use of the Haldane apparatus, as with any analytical procedure, difficulties may be encountered, and their sources are determined most readily by systematic consideration of their possible causes. The difficulties most likely to be encountered in the use of the Haldane apparatus, and their possible causes are:

Difficulty encountered	Possible causes
Leaks in apparatus:	Defective or deteriorated rubber tubing; tubing of improper size; improperly greased or poorly fitting stopcocks; defects in glassware; rubber stopper at base of combustion pipet improperly fitted; faulty glass-platinum seal in combustion pipet electrodes.
Expansion in volume when carbon dioxide is determined:	Leaks; insufficient water in burette to maintain sample in saturated condition.
Incorrect value for oxygen percentage in analysis of normal air:	Leaks; insufficient water in burette; potassium pyrogallate solution exhausted; absorption of nitrogen by fresh potassium pyrogallate solution; oxygen not completely absorbed; burette dirty or improperly calibrated.
Repeat burette readings do not agree in determination of a particular constituent:	Leaks; solutions exhausted; constituent not completely absorbed; in determination of combustibles, temperature of platinum spiral may be too low.
Expansion in volume after combustion:	Leaks; sample does not contain enough oxygen for complete combustion of combustibles.
Inexactness in combustion data: For example, methane is known to be the only combustible gas present, but ratio of contraction to carbon dioxide produced is not 2 to 1[20]	Leaks; insufficient water in burette; potassium hydroxide or potassium pyrogallate solution present in manifold, burette, or combustion pipet.

20/ Although the theoretical ratio of contraction to carbon dioxide produced in the combustion of methane is 2 to 1, some occasional variation from this ratio may occur when low concentrations of methane are determined because the possible error of burette reading (0.002 ml.) becomes a significant proportion of the observed volumes of contraction and carbon dioxide produced. For example, in the determination of methane in a concentration of 0.25 percent, the possible errors in burette reading may combine in such manner that combustion ratios ranging from 2.26:1 to 1.78:1 are produced. Unless definite reason exists to suspect that combustible gases other than methane may be present, such combustion ratios, in this low order of methane concentration, may be accepted as amenable to calculation in terms of methane, for, although much closer approach to the theoretical combustion ratio for methane is attainable with the Haldane type apparatus, the significance, magnitude, and frequency of occurrence of possible random error must be taken into account, as in considering any type of observed measurement.

Difficulty encountered	Possible causes
Liquid in compensating device appears sluggish in movement	Capillary between burette and potassium hydroxide pipet blocked by globule of water, mercury, or stopcock grease.
Liquids do not remain at marks in capillaries of pipets	Leaks; manifold not filled with inert gas.
Duplicate analyses do not agree within satisfactory limits	Any of the foregoing causes.

List of Equipment for Haldane Apparatus

Many of the items listed in connection with the Haldane apparatus are suitable for use in other gas-analysis procedures. Most of the items may be purchased from laboratory supply houses. Some may be constructed by the prospective user if he so desires.

Apparatus Assembly

The apparatus preferably should be obtained as a complete unit, including the supporting frame, all necessary glass parts, rubber tubing connections, and transformer and rheostat for power supply to combustion pipet. The transformer and rheostat are included in the assembly of some commercial apparatus. With others it may be necessary to purchase transformer and rheostat separately. The capacity of the transformer should be at least 150 watts, the primary should be suitable for use on the voltage and frequency available in the laboratory, and secondary voltage should be 6 to 8. The rheostat should be capable of carrying 2 to 3 amperes without overheating.

Spare Parts

It is good policy to keep on hand a supply of spare glass and electrical parts for the apparatus, as breakage or failure of a single part may make the whole apparatus inoperative. Some No. 28, B. & S.-gage platinum wire should be on hand for replacing burned-out or broken coils in the combustion pipet. Approximately 3 inches of wire are required for 1 coil.

Rubber Tubing

A supply of rubber tubing should be kept on hand, as connections on the apparatus must be replaced from time to time. For most commercial apparatus the following sizes are suitable:

For manifold - 3/16-inch inside diameter, 1/16- or 3/32-inch wall, pure gum.

For lower connection to carbon dioxide pipet - 1/4-inch inside diameter, 3/32-inch wall, pure gum or sulfur-free rubber, or chemical-resistant synthetic.

For leveling bulbs - 3/16-inch inside diameter, 1/8-inch wall, nitrometer or other durable tubing.

It is not wise to overstock on rubber tubing as it may deteriorate in time, even though not in use, unless stored in an inert atmosphere such as nitrogen.

Chemicals

The chemicals required in the actual analytical operations of the Haldane apparatus are potassium hydroxide and pyrogallic acid. Carbon dioxide is absorbed by a solution of potassium hydroxide and oxygen by a mixture of solutions of potassium hydroxide and pyrogallic acid. The solutions may be purchased from some chemical supply houses or may be prepared by the user of the apparatus. The approximate quantities of the reagents, in the solid form, required for analysis of 1,000 mine-air samples are 10 pounds of potassium hydroxide and one-half pound of pyrogallic acid.

Approximately 5 pounds of mercury are required as the confining liquid in the burette and combustion pipet of the Haldane apparatus. For maximum accuracy (particularly in the determination of carbon dioxide, which is quite soluble in water), mercury should be used as the medium for displacing the air sample from its container into the analytical apparatus. Mercury may be employed for this purpose only when glass sample containers are used. Metal sample containers usually are fabricated with soldered joints, which are destroyed by amalgamation when brought into contact with mercury. A welded-steel mercury container suitable for use in connection with the displacement of air samples is shown in figure 7. A container of this type requires about 35 pounds of mercury. When considerable quantities of mercury are required, it may be advantageous to purchase it in flask (76-pound) lots.

Mercury used in the analysis of gases should be clean, and particularly should not be contaminated with caustic materials that will introduce errors in the determination of carbon dioxide and methane by premature removal of carbon dioxide from the sample in the apparatus. If the mercury used in displacing the sample from its container is contaminated with caustic material, carbon dioxide will be removed from the sample before it is introduced into the apparatus. For this reason, equipment should be available for cleaning the mercury by acid treatment. The device shown in figure 8 is convenient for this purpose. The mercury first is strained through a cloth to remove grease and floating foreign matter and then is placed in the reservoir at the top of the apparatus from which it is allowed to flow slowly through a coarse cloth or other porous material, which breaks the stream of mercury into small particles or droplets. These particles of mercury descend through the cleaning mixture (5 parts by volume of nitric acid and 95 parts of water) in the long column. The acid-scrubbed mercury collects at the seal at the bottom of the column and may be withdrawn as needed. Vacuum stills[21] or devices in which mercury is mechanically agitated in air as a purifying procedure[22] may be used in laboratories where large quantities of mercury are to be cleaned.

A supply of distilled water should be available in the laboratory for preparing solutions and for rinsing glass parts of the apparatus after cleaning. For small laboratories, it may be simpler to purchase distilled water than to install a still.

21/ Kleiber, M., A Simple Apparatus for Mercury Distillation: Science, vol. 75, 1932, p. 196.

22/ Lawrence, J. B., Mercury the Purest Metal: Instruments, vol. 25, 1952, pp. 310-312, 363.

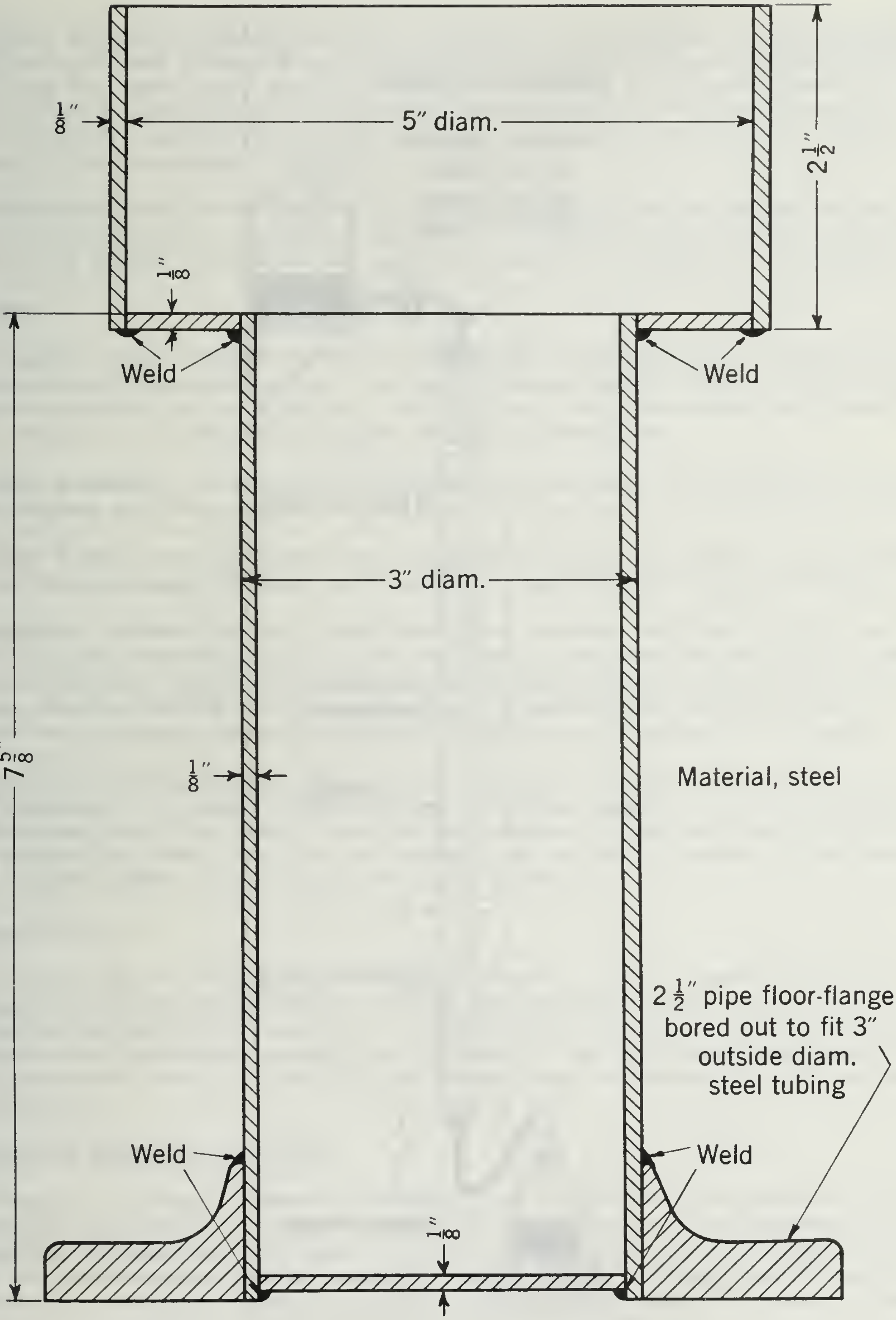

Figure 7. - Container for mercury used in displacing air samples.

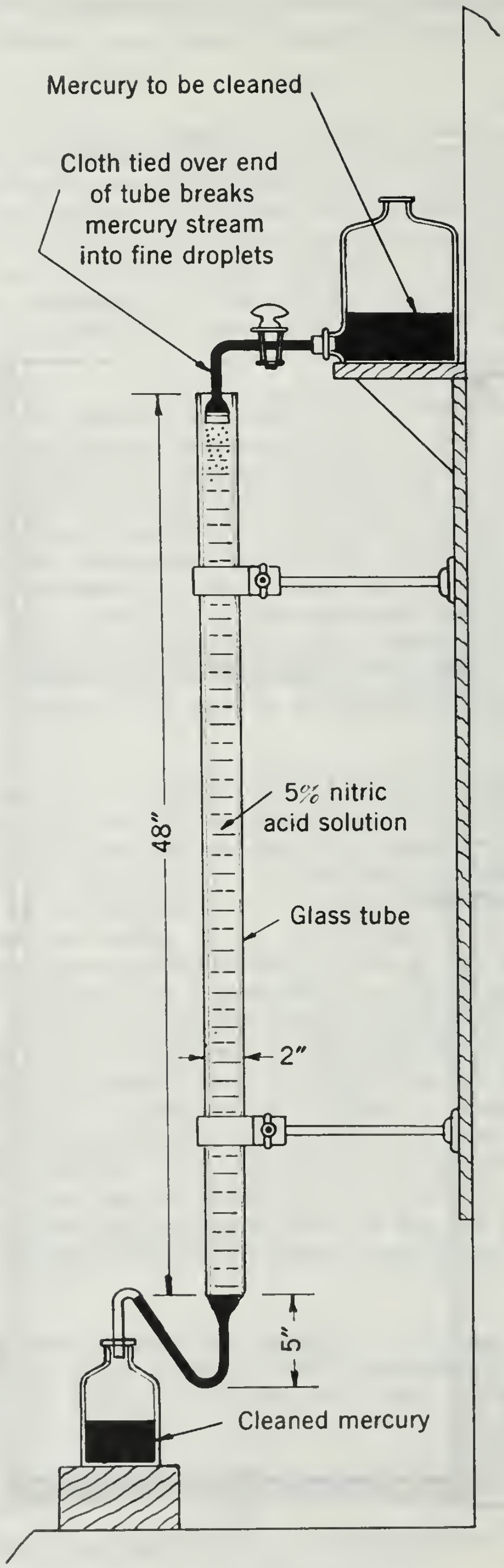

Figure 8. - Tower for acid-cleaning mercury used in gas analysis.

Nitric and sulfuric acids should be available for cleaning. A cleaning mixture of sulfuric and chromic acids is effective in removing grease films or deposits from the interior of the gas burette. One bottle each (approximately 2-1/2 liters) of nitric and sulfuric acids is the minimum supply for a small laboratory. Organic solvents, such as gasoline or benzene, never should be used in cleaning any part of the gas-analysis apparatus.

If solutions are to be prepared in the laboratory, a set of scales and weights should be provided for weighing the chemicals. A platform-type scale, commonly called a trip balance, sensitive to one-tenth gram, is suitable for this purpose.

Glassware

A supply of glass beakers should be available for preparing and dispensing solutions, adding cleaning solution or water to the gas burette, and similar purposes. Suggested sizes are 100 ml., 500 ml., and 4,000 ml. As glassware of this type is rather fragile, it is advisable to have several of each size.

Glass graduates, or measuring cylinders, are necessary in preparing solutions. Suggested sizes are 100 ml. and 1,000 ml.

Glass funnels are convenient for adding solutions to the pipets of the apparatus, for filling reagent bottles with solutions, and for similar operations.

Magnesium citrate bottles fitted with glass stoppers seating on rubber washers and held in place by spring clamps are convenient containers for storing the gas-analysis solutions. It is preferable to use several small containers rather than one large one for storing the oxygen-absorbing reagent, as in this way only a small volume of reagent comes into contact with air when the bottle is opened.

Soft glass tubing of both "shell" and "capillary" types is convenient for making connections to sample containers and for other purposes. Outside diameter of such tubing should be about 7 mm.; inside diameter of the capillary tubing should not be less than 2 mm. If the tubing is to be bent to shape in the laboratory, a Bunsen burner with a "wing" top will be needed.

Compressed Air

In operating the Haldane apparatus, low-pressure (2 to 3 pounds per square inch gage) compressed-air is needed to cool the combustion pipet and to stir the water in the jacket of the burette. If compressed air is not available at the laboratory, a small positive-pressure rotary blower driven by a fractional-horsepower motor will answer as an air supply. Such blowers may be obtained from laboratory supply houses.

Miscellaneous Materials and Tools

A supply of suitable grease is necessary to lubricate the stopcocks of the gas-analysis apparatus. As proper greasing of the stopcocks is an important part of preparing the apparatus for use, it is best to obtain a grease specially compounded for this purpose from a laboratory supply house. Ordinary pipe cleaners are useful for removing excess grease from stopcock bores, and soft cotton cloth is needed to wipe grease from the ground surfaces of stopcocks.

Triangular files, pliers, screw drivers, and soft copper wire (No. 22 B. & S. gage) will be found necessary in maintaining and adjusting the apparatus.

Portable Orsat Gas-Analysis Apparatus[23]

The portable Orsat apparatus is suitable for determining carbon dioxide, oxygen, carbon monoxide, methane, and nitrogen in the atmospheres of sealed areas or the analysis of oxygen-deficient atmospheres or considerable accumulations of carbon dioxide, methane, or nitrogen in unventilated places.

Accuracy of determination of carbon dioxide, oxygen, and carbon monoxide is 0.2 to 0.3 percent.

Methane may be determined in concentrations below, within, or above the flammable or "explosive" range with an accuracy of 0.2 to 1.0 percent, depending on the concentration of methane.

The apparatus is suitable for either laboratory or field use.

The apparatus is not suitable for accurate determination of low concentrations of methane in the air of ventilated places, such as main returns and splits, and is not suitable for determination of carbon monoxide in concentrations of less than 0.3 percent.

A number of types and designs of portable apparatus are available for analyzing various gaseous mixtures. For the analysis of mine atmospheres, the apparatus should be fitted with a straight 100 ml. burette (no bulb at top of burette) and should be suitable for determining carbon dioxide, oxygen, carbon monoxide, and methane. The first three gases are determined by absorption and methane is determined either by combustion on a heated platinum-wire coil, or by oxidation on a heated, specially prepared catalyst. In the type of apparatus using the combustion pipet a shield of wire screen or shatter-proof glass should be provided to protect the operator in event of an explosion. If the apparatus is fitted with a transformer or other electrical equipment, the purchaser should specify voltage and frequency to conform with that available in the laboratory. The combustion pipet of some types of apparatus may be operated on dry cells (No. 6) when used in the field. Such batteries should not be obtained until the apparatus actually is to be used, as they deteriorate in storage.

Many of the items listed under the Haldane apparatus are suitable for use in connection with the portable Orsat apparatus. Such items include rubber tubing, glass tubing, stopcock grease, sulfuric acid, platinum wire for the combustion pipet, and solutions for the absorption of carbon dioxide and oxygen. When the portable Orsat apparatus is used in the laboratory, many of the facilities provided for the Haldane apparatus may be used. These include power supply, compressed air for cooling the combustion pipet, and vessels in which samples are displaced from their containers. Carbon monoxide usually is determined with the portable Orsat apparatus by absorption in cuprous chloride solution. One pound of cuprous chloride (solid), one bottle (6 pounds) of chemically pure hydrochloric acid, and one-fourth pound of stannous chloride (solid) will make enough of the cuprous chloride reagent to analyze 100 to 300 samples, depending on the percentage of carbon monoxide in the samples.

23/ Berger, L. B., and Schrenk, H. H., Sampling and Analysis of Mine Atmospheres: Bureau of Mines Miners' Circ. 34, 1948 rev., 103 pp.

The confining liquid (water) in the burette and combustion pipet of the portable Orsat apparatus is maintained in a slightly acid condition by adding sulfuric acid. A small quantity of an indicator (methyl orange) is added to the water, which colors it red so long as the water remains acid. One ounce, or even a smaller quantity, of methyl orange indicator will suffice for ordinary needs.

When the portable Orsat apparatus is used in the field, as in analyzing gases from a sealed fire area in a coal mine, the analyst also may be responsible for collecting gas samples. In such situations the sampling equipment required, in addition to suitable sample containers, consists of 4 to 6 feet of soft copper tubing (1/4-inch outside diameter) for sampling through seals, a rubber aspirator bulb for pumping gas through the sampling tube, a water gage (a glass U-tube, which may be made in the laboratory) for measuring gas pressure on seals, and suitable rubber tubing connections. Sampling techniques are discussed in detail in another Bureau of Mines publication.[24]

Laboratory-Type Orsat Apparatus[25, 26]

The laboratory-type Orsat apparatus has the same field of application as the portable Orsat, and, in addition, hydrogen and higher hydrocarbons such as ethane may be determined.

The apparatus is more accurate than the portable Orsat, but the accuracy is not adequate for determining low concentrations of methane in the air of ventilated places.

The laboratory-type Orsat apparatus suitable for the analysis of mine atmospheres usually is fitted with a straight 100-ml. burette, 3 pipets for the determination of carbon dioxide, oxygen, and carbon monoxide by absorption, and a combustion pipet for determination of methane and other combustible gases. To obtain maximum utility from this type of apparatus, it should include a tube containing copper oxide (which may be heated by an electric furnace) for the determination of carbon monoxide and hydrogen simultaneously or individually. With this arrangement, analysis may be made for four combustible gases (carbon monoxide, hydrogen, methane, and ethane). In some commercial apparatus the combustion (hot-wire) pipet is replaced by a tube of specially prepared catalyst for combustion of methane and ethane. For maximum accuracy, mercury should be used as the confining liquid in burette and combustion pipet or tube. In the type of apparatus employing the combustion pipet, a shield of wire screen or shatter-proof glass should be provided to protect the operator in event of an explosion. Electrical accessories should be specified, in regard to type of current, voltage, and frequency, to conform with the power supply available in the laboratory.

Many of the items mentioned in connection with the Haldane and portable Orsat types are suitable for use with the laboratory-type Orsat. These include rubber tubing, stopcock grease, cleaning solutions, sample-displacement vessels,

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24/ See work cited in footnote 23 (p. 38).

25/ Burrell, G. A., and Seibert, F. M. (rev. by G. W. Jones), The Sampling and Examination of Mine Gases and Natural Gas: Bureau of Mines Bull. 197, 1926, 108 pp.

26/ Fieldner, A. C., Jones, G. W., and Holbrook, W. F., The Bureau of Mines Orsat Apparatus for Gas Analysis: Bureau of Mines Tech. Paper 320, 1925, 18 pp.

compressed-air for cooling the combustion pipet and copper oxide tube, and reagents for the absorption of carbon dioxide and oxygen.27/ Cuprous chloride solution may be used for the absorption of carbon monoxide, although a preferred reagent for this purpose in the laboratory-type Orsat is composed of cuprous sulfate, beta-naphthol, and sulfuric acid.28 29/ This reagent may be purchased already prepared from some laboratory supply houses that specialize in gas-analysis equipment.

Pyrotannic Method for Determining Carbon Monoxide30 31 32/

The pyrotannic acid method is suitable for determining low concentrations (0.01 to 0.20 percent) of carbon monoxide in the air of ventilated places or in the gases from sealed fire areas when the fire is nearly extinguished and the area is cooling. The method may be considered specific for carbon monoxide in mine air samples, as the color reaction involved depends on the reaction of carbon monoxide with the hemoglobin of blood.

The accuracy of the method is 0.01 in the range 0.00 to 0.05 percent of carbon monoxide, 0.02 in the range 0.05 to 0.10 percent, and 0.03 in the range 0.10 to 0.20 percent. When blood from one source is used in the test medium for both a "blank" or control specimen for comparison purposes and as the reagent for analyzing an air sample, a blood saturation of 10 percent (equivalent to 0.01 percent of carbon monoxide in air) is readily evident to persons with normal color perception and traces below this concentration may be detected.

The method is suitable, also, for determining carbon monoxide in the blood of persons overcome or killed by that gas.

The method is suitable for use in the field as well as in the laboratory.

The method is particularly suitable for occasional use or in laboratories where only a few samples are to be analyzed for carbon monoxide.

The pyrotannic apparatus may be purchased as an essentially complete unit consisting of color standards, blood lancet, blood-dilution pipet, required test tubes, and a supply of the pyrotannic reagent. This reagent consists of equal parts, by weight, of pyrogallic and tannic acids thoroughly mixed and ground together to a fine powder. One ounce of each of the ingredients will make enough of the mixture to conduct more than 1,000 tests or analyses. The mixed reagent must be kept in a tightly stoppered bottle, as it will absorb moisture from the air. In the analysis of air samples by the pyrotannic-acid method, any glass bottle that may be

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27/ See Preparation of Solutions, under section on Haldane-Type Gas Analysis Apparatus.

28/ Work cited in footnote 23 (p.38).

29/ Berger, L. B., and Schrenk, H. H., Methods for the Detection and Determination of Carbon Monoxide: Bureau of Mines Tech. Paper 582, 1938, 30 pp. (Rev. 1954. To be published.)

30/ Sayers, R. R., and Yant, W. P., The Pyrotannic Acid Method for the Quantitative Determination of Carbon Monoxide in Blood and in Air; Its Use in the Diagnosis and Investigation of Cases of Carbon Monoxide Poisoning: Bureau of Mines Tech. Paper 373, 1927, 18 pp.

31/ Work cited in footnote 29.

32/ Forbes, J. J., and Grove, G. W., (rev. by McElroy, G. E., Watson, H. A., Coggeshall, E. J., Dornenburg, D. D., and Berger, L. B.), Mine Gases and Methods for Detecting Them: Bureau of Mines Miners' Circ. 33, 1954, 82 pp.

stoppered tightly will serve as a sample container. The volume of the sample bottles must be known, however, as volume of sample enters into the calculation of the percentage of carbon monoxide in the air sample. Bottles of 100- to 250-ml. capacity generally are used, but containers of smaller volume may be used if the supply of sample is limited.

"Phosphomolybdic Acid" Method for Determining Carbon Monoxide[33]

The phosphomolybdic acid method is suitable for determining low concentrations (0.002 to 0.06 percent) of carbon monoxide in the air of ventilated places or in the gases from sealed fire areas when the fire is nearly extinguished and the area is cooling.

The method is more sensitive and accurate than the pyrotannic acid method for carbon monoxide but is more complicated in respect to apparatus and technique.

The method is best adapted to use in laboratories where a considerable number of samples are to be analyzed for carbon monoxide and where the method is in more or less continuous use.

The method is not suitable for field use.

A list of equipment for determining carbon monoxide by the phosphomolybdic acid method is not included in this publication, as the reference cited contains this information in detail.

Phenoldisulfonic Acid Method for Determining Oxides of Nitrogen[34]

The phenoldisulfonic acid method is suitable for determining total toxic oxides of nitrogen in concentrations that may be encountered (a) in the air of working places after blasting, (b) as a result of the use of internal combustion (diesel) engines, or (c) in comparatively high concentrations such as may be present in the undiluted exhaust gases of internal combustion engines.

The method necessitates collecting samples in specially prepared containers.

The analytical procedure may be conducted only in a laboratory.

Reagents

The following reagents are required in determining oxides of nitrogen in mine air samples:

Potassium hydroxide.

33/ Polis, B. D., Berger, L. B., and Schrenk, H. H., Colorimetric Determination of Low Concentrations of Carbon Monoxide by Use of a Palladium Chloride-Phosphomolybdic Acid-Acetone Reagent: Bureau of Mines Rept. of Investigations 3785, 1944, 13 pp.

34/ Beatty, R. L., Berger, L. B., and Schrenk, H. H., Determination of the Oxides of Nitrogen by the Phenoldisulfonic Acid Method: Bureau of Mines Rept. of Investigations 3687, 1943, 17 pp.

Phenoldisulfonic acid reagent, which is prepared from concentrated sulfuric acid, fuming sulfuric acid, and phenol.

Litmus or other indicating test paper.

Ammonium hydroxide.

Potassium nitrate.

Distilled water.

Specially prepared glass containers are necessary in collecting samples for determining oxides of nitrogen. It is possible that these containers, already prepared, may be obtained from laboratory supply houses that specialize in gas-analysis equipment. If the containers are to be prepared in the laboratory, the following reagents will be required:

Tenth-normal sulfuric acid solution, reagent grade.

Hydrogen peroxide, 30 percent, reagent grade.

The specially prepared sample containers (see fig. 3) are intended primarily to furnish a simple and convenient method for sampling underground atmospheres for determining oxides of nitrogen. Preparation of such containers requires glass-blowing facilities and a pump for evacuating the container before it is sealed. Other means suitable for collecting the samples may be devised if these facilities are not available.

A small rubber cap is used to seal the vacuum-type container for oxides of nitrogen after the sample has been collected. These caps are known as rubber policemen in the laboratory parlance and may be obtained from laboratory supply houses.

Apparatus

In the analytical procedure, the following equipment is required:

Glass beakers of 150-ml. capacity, into which the liquid absorbent from the sample container is transferred.

Cover glasses to fit the above beakers. These are to prevent possible loss of material from the beakers when their contents are evaporated, and to prevent the entrance of foreign material that might contaminate the contents of the beaker.

An electric hotplate for the evaporation procedure.

Graduates and pipets suitable for measuring reagent volumes.

The final step in determining oxides of nitrogen is a comparison of the intensity of color produced by chemical treatment of the samples, with the color of "standards" similarly processed. The comparison may be made visually by matching the colors in Nessler tubes to which the colored solutions are transferred. This method is the simplest and least expensive for the small laboratory, where only a limited number of samples are to be analyzed for oxides of nitrogen. When a greater number of analyses are to be made, a colorimeter of the photoelectric

type is preferable, as an instrument of this type eliminates visual fatigue in color perception, which is particularly notable in judging the intensity of the pale yellows that are produced in this analytical procedure. A colorimeter of this type may be used to advantage also in determining carbon monoxide by the phosphomolybdic acid method referenced in this circular.

Other methods are available for determining certain toxic oxides of nitrogen[35] and for the specific determination of nitrogen dioxide.[36]

Gas Analysis by Infrared Absorption

Certain components of gaseous mixtures may be determined by measuring their ability to absorb infrared radiation. Compounds such as carbon dioxide, carbon monoxide, water vapor, methane, and other hydrocarbons absorb infrared radiation, whereas symmetrical diatomic gases such as oxygen, nitrogen, and hydrogen do not. The infrared wavelength, or frequency of vibration, at which different compounds absorb depends on the mass of the atoms in the compound, their geometrical spacing, and the chemical bond forces between the atoms that constitute the compound. These characteristics of a molecular species determine the natural frequency of vibration of the atoms that constitute that compound. When infrared radiation of the same frequency or wavelength is imposed upon the compound, absorption of the infrared energy occurs; when infrared energy of other frequencies is imposed upon the same gaseous compound absorption does not occur. Thus, different compounds exhibit characteristic absorption behavior when subjected to infrared radiation, and it is upon this principle that gas analysis by infrared absorption is based.

In application of this principle, a beam of infrared radiation from a suitable source (usually an electrically heated resistance element or glower) is passed through a cell that contains the gas sample under examination and then is directed through an optical path to a detecting element that measures the intensity or energy of the radiation that emerges from the cell as compared to the energy of the beam that enters the cell. Thus, a means is obtained for measuring the capacity of the gas or gases in the analyzing cell to absorb infrared radiation. Since infrared radiation lies within the heat portion of the spectrum of vibration frequencies, the detecting element is a heat-sensitive device (for example, a thermocouple or bolometer) that is capable of absorbing heat energy and transforming it into electrical energy that may be amplified and recorded. Various schemes have been developed for applying this basic principle to analysis by infrared absorption.

In the dispersion-type infrared spectrometer the radiation that passes through the gas sample is separated or dispersed by a continuously variable element of the optical system, such as a prism rotating through an arc so that at a given time the degree of infrared absorption is measured at only one particular wavelength or a very narrow band of wavelengths. Thus, the characteristic absorption pattern of a particular compound may be determined in respect to the wavelengths at which that compound absorbs the infrared. In this manner different gases in a mixture may be identified by their characteristic behavior, and the concentration of a particular constituent of the mixture may be determined by measuring the magnitude of absorption at the wavelength, or wavelengths, at which that gas is known to exhibit an absorption maximum or peak.

35/ Patty, F. A., and Petty, G. M., Nitrite Field Method for the Determination of Oxides of Nitrogen (Except N_2O and N_2O_5): Jour. Ind. Hyg. and Toxicol., vol. 25, 1943, pp. 361-365.

36/ Saltzman, B. E., Colorimetric Microdetermination of Nitrogen Dioxide in the Atmosphere: Anal. Chem., vol. 26, 1954, pp. 1949-1955.

In the nondispersion-type analyzer two beams of infrared radiation are passed through a cell that contains the gas mixture under examination, and also through cells that contain certain components of the mixture which absorb or filter out portions of the infrared spectrum to obtain selectivity and make it possible to determine a single constituent of the gas mixture. The finally emerging radiation is measured by suitable detecting elements. Various modifications of this filtration principle are possible, and have been employed to obtain selectivity and a high degree of sensitivity in response.

The dispersion-type infrared spectrometer is primarily a laboratory instrument for the qualitative identification of certain components of gaseous mixtures and for the quantitation of components thus identified. The nondispersion-type analyzer is primarily adaptable to the examination of mixtures of known qualitative composition and is applicable in this field not only in the laboratory but also in plant operations where continuous control analysis of products is desired.

The foregoing discussion of gas analysis by infrared absorption is merely a very brief presentation of the principles involved. Discussion of the theory of infrared absorption or detailed description of instruments that have been developed for this method of analysis are not within the scope of this circular.

LABORATORY PLAN

The required size or floor space of the gas-analysis laboratory will depend, of course, on the volume and variety of analytical work to be done. In general, the equipment is best housed in a separate room used only for gas analysis. The room should be arranged so that it is free of cross drafts and not subject to sudden changes of temperature. Facilities such as electric power, tap water, compressed air, and fuel gas should be available.

In addition to a suitable bench for mounting the gas-analysis apparatus, the laboratory equipment should include a flattop table or bench that may be used in preparing solutions or for analytical work, a sink, shelves for storing chemicals and gas-sample containers, and lockers in which spare glass parts of the gas-analysis apparatus may be stored. Means should be provided for orderly filing of sample records and analytical results.

The method of mounting the gas-analysis apparatus will depend on the structural features of the particular equipment obtained. The Haldane-type apparatus or the laboratory Orsat should be more or less permanently installed on a stout table or bench that will not be subject to shock or vibration. The apparatus should be located so that it is not subject to sudden changes in temperature, as by drafts from open doors or windows or by excessive heat from room-heating appliances.

Figure 9 shows the design of a bench for gas-analysis apparatus used in the Gas Analysis Laboratory of the Bureau of Mines. The figure shows a section of bench suitable in size for mounting one apparatus; the length of bench may be increased to accommodate any desired number of units, and for a large laboratory, apparatus may be mounted on both sides of the bench.

The figure as drawn represents the mounting of a Haldane-type apparatus, but the laboratory-type Orsat may be installed similarly. The manifold, pipets, and electrical controls are attached to panel *a*; the burette is supported by clamps attached to rod *b*; the leveling bulb is supported on rod *c*. Rods *b* and *c* are clamped to the pipe framework, *d*, which extends the length of the bench and permits

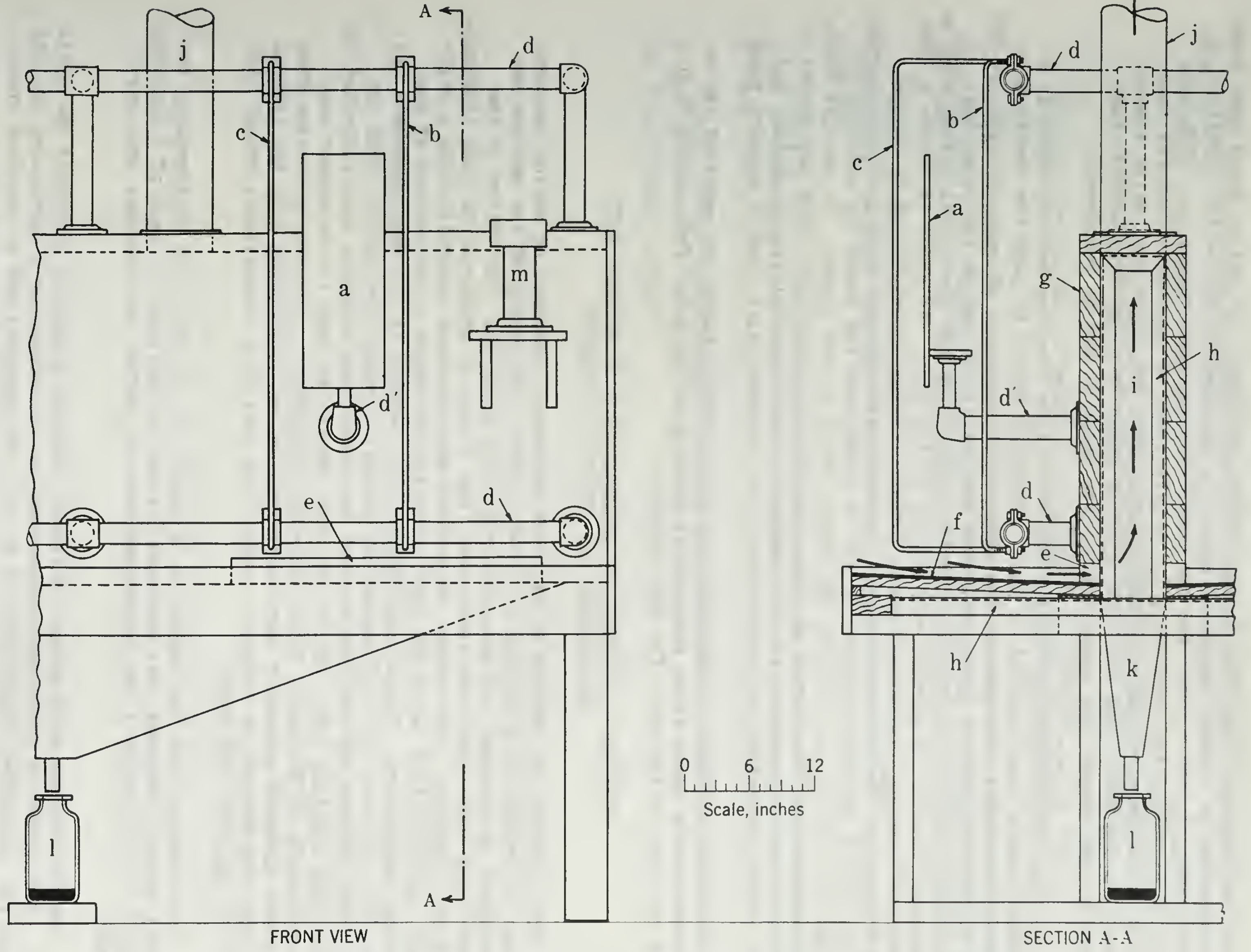

Figure 9. - Bench for gas analysis apparatus, as used in Bureau of Mines gas-analysis laboratory.

lateral adjustment of the rods to any desired position. It may be noted that panel a is supported on a short length of pipe, d', attached to the center partition, g, as are frames, d, and a shelf for the sample-displacement vessel, m. With this system of mounting, the bench top, f, is left clear of apparatus supports, and spilled mercury may be removed by brushing it from the bench top, which slopes slightly to the rear, into the slot, e, from which it drops into welded-steel trough, k, and thence into reservoir l, from which it may be recovered.

As some potential health hazard may exist from inhaling mercury vapor in a laboratory where this material is used, provision should be made for ventilation of the gas-analysis laboratory. The most prolific sources of mercury vapor are the fine droplets of mercury that are formed when it is spilled on the bench top. Accordingly, ventilation is most effective if provided at that level rather than by an overhead hood or by general ventilation of the room. As shown in figure 9, the center partition, g, is hollow, being formed of 2-inch plank bolted to channel-iron frames, h. The enclosed space, i, communicates through duct j with an exhaust fan, so that a continuous stream of air is drawn over the bench top and into i through the slot, e, as shown by the heavy arrows in the figure. In the Gas Analysis Laboratory of the Bureau of Mines, approximately 250 cubic feet per minute of ventilating air is provided in this manner for each gas-analysis apparatus, and tests of the laboratory air have shown it to be essentially free of mercury vapor.

As shown in figure 9, approximately 3-1/2 feet of bench are required for an apparatus, and a clear floor space of at least 3-1/2 by 3-1/2 feet should be provided in front of the bench for the operator.

APPENDIX: ACCURACY OF DETERMINATION OF METHANE WITH THE HALDANE GAS ANALYSIS APPARATUS

Test mixtures of methane in air were accurately prepared by adding measured volumes of methane to a chamber of known volume. The purity of the methane was established by chemical and mass-spectrographic analyses. The volume of the chamber (926 cubic feet) was calculated from 3 sets of measurements made independently by 3 persons. The volumes of methane were measured carefully with a calibrated, wet-type test meter and were corrected for water vapor content at the existing temperature. Three concentrations of methane in air were prepared: (1) 0.25, (2) 0.23, and (3) 0.27 percent by volume. Twenty-five samples from the first test mixture and ten from each of the other test mixtures were collected in vacuum-type sampling tubes and sealed with wax-filled caps in the manner used conventionally by Bureau of Mines coal-mine inspectors. The sample bottles from the three mixtures purposely were intermixed before introducing into the laboratory and were treated as routine samples from coal mine inspections, except that multiple analyses were made.

Each sample, with the exception of sample No. 14 which was accidentally destroyed after 4 analyses, was analyzed 6 times in duplicate by each of 3 analysts. Sample 10 from mixture 1 was broken accidentally before any analyses were performed.

Twelve analysts each using a different Haldane apparatus performed the analyses. The number of individual determinations of methane by a particular analyst (hence per apparatus) ranged from 14 to 32. The analysts had no previous knowledge of the composition of the prepared test mixtures and, because of the mixed order of numbering the samples, would have been unable to associate any individual sample with a particular test mixture.

The concentration of methane was calculated on a volume basis as follows:

Volume of methane in sample =

$$\frac{\text{contraction caused by combustion + carbon dioxide formed}}{3}$$

$$\text{Percent, by volume, of methane} = \frac{\text{volume of methane}}{\text{original volume of sample}} \times 100$$

Table 2 shows the experimentally determined methane concentration obtained in each analysis, the average concentration for each sample tube from which six analyses were made, and the overall average of the samples from each test mixture.

Table 3 shows the averages of pairs of determinations by individual Haldane apparatus of methane concentration in each sample from the three known methane-air mixtures.

Table 4 shows the averages of 4 determinations - the possible combinations of pairs of determinations from a given sample by 2 individual apparatuses - of methane concentration in each sample from the 3 known methane-air mixtures.

Table 5 shows the frequency distribution of experimentally determined methane values expressed in relation to deviation in percent, by volume, of methane from the true methane content.

TABLE 2. - Summary of analytical results showing individual determinations of methane concentration in each sample from three test mixtures containing known concentrations of methane in air

Sample No.	Test mixture No. 1: 0.25 percent methane in air						
	Methane by analysis, percent by volume						
	Individual determinations						
	Pair (1)		Pair (2)		Pair (3)		Average
4	0.25	0.24	0.25	0.24	0.24	0.24	0.24
7	.24	.24	.25	.25	.24	.26	.25
8	.25	.24	.25	.25	.26	.25	.25
9	.25	.24	.25	.25	.24	.25	.25
13	.25	.25	.24	.24	.25	.25	.25
14	.26	.25	.25	.24	--	--	--
17	.25	.24	.25	.25	.24	.23	.24
18	.24	.24	.25	.24	.25	.25	.25
19	.25	.25	.26	.26	.26	.24	.25
20	.25	.25	.26	.27	.24	.23	.25
23	.25	.25	.24	.25	.25	.24	.25
24	.25	.26	.24	.26	.24	.24	.25
27	.24	.25	.24	.24	.25	.26	.25
28	.24	.25	.23	.25	.22	.23	.24
29	.25	.24	.25	.25	.24	.24	.25
30	.24	.25	.25	.25	.25	.25	.25
33	.24	.24	.25	.25	.26	.26	.25
34	.24	.24	.26	.26	.25	.25	.25
35	.24	.25	.26	.26	.26	.25	.25
38	.26	.25	.25	.25	.24	.25	.25
39	.25	.25	.26	.25	.25	.25	.25
40	.25	.25	.26	.25	.25	.25	.25
44	.25	.25	.25	.25	.25	.25	.25
45	.25	.26	.25	.25	.26	.26	.26

	Percent		Percent
Minimum individual determination:	0.22	Average:	0.25
Maximum individual determination:	0.27		

	Percent
Minimum average of an individual sample:	0.24
Maximum average of an individual sample:	0.26

Sample No.	Test mixture No. 2: 0.23 percent methane in air						
	Methane by analysis, percent by volume						
	Individual determinations						
	Pair (1)		Pair (2)		Pair (3)		Average
1	0.23	0.23	0.22	0.22	0.22	0.23	0.23
2	.26	.25	.22	.22	.23	.23	.24
3	.23	.24	.24	.23	.21	.23	.23
11	.23	.22	.22	.21	.24	.21	.22
12	.24	.22	.23	.23	.23	.21	.23
21	.23	.23	.22	.21	.22	.22	.22
22	.23	.23	.22	.22	.23	.24	.23
31	.23	.22	.23	.22	.24	.22	.23
32	.26	.24	.22	.22	.23	.22	.23
37	.22	.22	.21	.23	.22	.24	.22

	Percent		Percent
Minimum individual determination:	0.21	Average:	0.23
Maximum individual determination:	0.26		

	Percent
Minimum average of an individual sample:	0.22
Maximum average of an individual sample:	0.24

Sample No.	Test mixture No. 3: 0.27 percent methane in air						
	Methane by analysis, percent by volume						
	Individual determinations						
	Pair (1)		Pair (2)		Pair (3)		Average
5	0.26	0.26	0.27	0.26	0.26	0.26	0.26
6	.26	.26	.30	.29	.26	.26	.27
15	.26	.26	.26	.26	.27	.27	.26
16	.28	.27	.25	.27	.26	.26	.27
25	.26	.25	.27	.27	.26	.28	.27
26	.26	.24	.28	.26	.26	.26	.26
36	.26	.26	.26	.27	.28	.27	.27
41	.27	.27	.26	.26	.27	.26	.27
42	.27	.27	.27	.27	.26	.27	.27
43	.25	.26	.26	.26	.28	.28	.27

	Percent		Percent
Minimum individual determination:	0.24	Average:	0.27
Maximum individual determination:	0.30		

	Percent
Minimum average of an individual sample:	0.26
Maximum average of an individual sample:	0.27

TABLE 3. - Summary of analytical results showing averages of pairs of determinations by individual Haldane apparatus of methane concentration in each sample from three known methane-air mixtures

Test mixture No. 1: 0.25 percent methane in air				Test mixture No. 2: 0.23 percent methane in air				Test mixture No. 3 0.27 percent methane in air			
Sample No.	CH_4, percent by volume: Average of pairs			Sample No.	CH_4, percent by volume: Average of pairs			Sample No.	CH_4, percent by volume: Average of pairs		
	Pair(1)	Pair(2)	Pair(3)		Pair(1)	Pair(2)	Pair(3)		Pair(1)	Pair(2)	Pair(3)
4	0.25	0.25	0.24	1	0.23	0.22	0.23	5	0.26	0.27	0.26
7	.24	.25	.25	2	.26	.22	.23	6	.26	.30	.26
8	.25	.25	.26	3	.24	.24	.22	15	.26	.26	.27
9	.25	.25	.25	11	.23	.22	.23	16	.28	.26	.26
13	.25	.24	.25	12	.23	.23	.22	25	.26	.27	.27
14	.26	.25	--	21	.23	.22	.22	26	.25	.27	.26
17	.25	.25	.24	22	.23	.22	.24	36	.26	.27	.28
18	.24	.25	.25	31	.23	.23	.23	41	.27	.26	.27
19	.25	.26	.25	32	.25	.22	.23	42	.27	.27	.27
20	.25	.27	.24	37	.22	.22	.23	43	.26	.26	.28
23	.25	.25	.25								
24	.26	.25	.24								
27	.25	.24	.26								
28	.25	.24	.23								
29	.25	.25	.24								
30	.25	.25	.25								
33	.24	.25	.26								
34	.24	.26	.25								
35	.25	.26	.26								
38	.26	.25	.25								
39	.25	.26	.25								
40	.25	.26	.25								
44	.25	.25	.25								
45	.26	.25	.26								

TABLE 4. - Summary of analytical results showing averages of 4 determinations (2 each on 2 individual Haldane apparatus) of methane concentration in each sample from 3 known methane-air mixtures. The values of individual determinations contributing to the pair averages shown in table 3 were used to compute averages of two pairs

Test mixture No. 1: 0.25 percent methane in air				Test mixture No. 2: 0.23 percent methane in air				Test mixture No. 3: 0.27 percent methane in air			
	CH_4, percent by volume: Averages of two pairs (4 determinations)				CH_4, percent by volume: Averages of two pairs (4 determinations)				CH_4, percent by volume: Averages of two pairs (4 determinations)		
Sample No.	Pairs(1) and (2)	Pairs(1) and (3)	Pairs(2) and (3)	Sample No.	Pairs(1) and (2)	Pairs(1) and (3)	Pairs(2) and (3)	Sample No.	Pairs(1) and (2)	Pairs(1) and (3)	Pairs(2) and (3)
4	0.25	0.24	0.24	1	0.23	0.23	0.22	5	0.26	0.26	0.26
7	.25	.25	.25	2	.24	.24	.23	6	.28	.26	.28
8	.25	.25	.25	3	.24	.23	.23	15	.26	.27	.27
9	.25	.25	.25	11	.22	.23	.22	16	.27	.27	.26
13	.25	.25	.25	12	.23	.23	.23	25	.26	.26	.27
14	.25	--	--	21	.22	.23	.22	26	.26	.26	.27
17	.25	.24	.24	22	.23	.23	.23	36	.26	.27	.27
18	.24	.25	.25	31	.23	.23	.23	41	.27	.27	.26
19	.26	.25	.26	32	.24	.24	.22	42	.27	.27	.27
20	.26	.24	.25	37	.22	.23	.23	43	.26	.27	.27
23	.25	.25	.25								
24	.25	.25	.25								
27	.24	.25	.25								
28	.24	.24	.23								
29	.25	.24	.25								
30	.25	.25	.25								
33	.25	.25	.26								
34	.25	.25	.26								
35	.25	.25	.26								
38	.25	.25	.25								
39	.25	.25	.25								
40	.25	.25	.25								
44	.25	.25	.25								
45	.25	.26	.26								

TABLE 5. - Frequency distribution of experimentally determined methane values expressed in relation to deviation in percent, by volume, of methane from the true methane content of three known methane-air mixtures

Test mixture number and known concentration		Single methane determination		Average of two methane determinations--on same apparatus		Average of 4 methane determinations--2 on each of 2 different apparatuses		Average of 6 methane determinations--2 on each of 3 different apparatuses	
		Number	Percent of total	Number	Percent of total	Number	Percent of total	Number	Percent of total
	True value +0.03	0	0	0	0	0	0	0	0
1	True value + .02	1	.7	1	1.4	0	0	0	0
(0.25	True value + .01	23	16.2	14	19.7	8	11.4	1	4.3
percent	True value	74	52.1	43	60.6	51	72.9	19	82.7
methane)	True value - .01	39	27.5	12	16.9	10	14.3	3	13.0
	True value - .02	4	2.8	1	1.4	1	1.4	0	0
	True value - .03	1	.7	0	0	0	0	0	0
	Total	142	100.0	71	100.0	70	100.0	23	100.0
	True value +0.03	2	3.3	1	3.3	0	0	0	0
2	True value + .02	1	1.7	1	3.3	0	0	0	0
(0.23	True value + .01	8	13.3	3	10.0	5	16.7	1	10.0
percent	True value	21	35.0	14	46.7	18	60.0	6	60.0
methane)	True value - .01	22	36.7	11	36.7	7	23.3	3	30.0
	True value - .02	6	10.0	0	0	0	0	0	0
	True value - .03	0	0	0	0	0	0	0	0
	Total	60	100.0	30	100.0	30	100.0	10	100.0
	True value +0.03	1	1.7	1	3.3	0	0	0	0
3	True value + .02	1	1.7	0	0	0	0	0	0
(0.27	True value + .01	6	10.0	3	10.0	2	6.7	0	0
percent	True value	17	28.3	11	36.7	15	50.0	7	70.0
methane)	True value - .01	31	51.6	14	46.7	13	43.3	3	30.0
	True value - .02	3	5.0	1	3.3	0	0	0	0
	True value - .03	1	1.7	0	0	0	0	0	0
	Total	60	100.0	30	100.0	30	100.0	10	100.0
	True value +0.03	3	1.1	2	1.5	0	0	0	0
	True value + .02	3	1.1	2	1.5	0	0	0	0
1, 2,	True value + .01	37	14.1	20	15.3	15	11.5	2	4.7
and 3	True value	112	42.8	68	52.0	84	64.6	32	74.4
composite	True value - .01	92	35.1	37	28.2	30	23.1	9	20.9
	True value - .02	13	5.0	2	1.5	1	0.8	0	0
	True value - .03	2	.8	0	0	0	0	0	0
	Total	262	100.0	131	100.0	130	100.0	43	100.0

In table 5, from left to right, it is evident that the limits of deviation of experimentally determined methane values from the true values became narrower as the number of determinations used for computing the methane content was increased. In other words, the greater the number of determinations made, the closer the experimentally determined average value was to the true methane content of the test mixture. In these tests it was found: (1) Any single determination of methane might vary from the true value by ±0.03 percent, by volume; (2) the average of two methane determinations by an individual apparatus might vary from the true value by ±0.02 to ±0.03 percent, by volume; (3) the average of 4 methane determinations - 2 each by 2 individual apparatus - might vary from the true value by ±0.01 percent (1 value out of 130 showed a deviation of -0.02 from the true value); (4) the average of 6 methane determinations - 2 each by 3 individual apparatus - might vary from the true value by ±0.01 percent, by volume.

The discussion above relates to the maximum variations observed in these tests. Examination of the frequency of occurrence of experimental values in relation to the positive and negative deviations from the true values shows that for the 3 test mixtures experimental average values based on 4 or 6 determinations agreed with the known values in 50 to 83 percent of the cases, or, if the results for the 3 test mixtures be combined, the averages of 4 to 6 determinations agreed with the known values in 65 to 74 percent of the cases. In those instances where deviation from the true value did occur, the experimentally determined values were low more frequently than high.

Bureau of Mines
Information Circular 7729

MARKETING SHEET MICA

BY ROBERT D. THOMSON

United States Department of the Interior — November 1955

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UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
J. J. Forbes, Director

November 1955

MARKETING SHEET MICA

by

Robert D. Thomson 1/

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1/ Commodity-industry analyst, Branch of Ceramic and Fertilizer Materials, Bureau of Mines, Washington, D. C.

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INTRODUCTION

Sheet mica is an important material in the manufacture of electronic and electrical equipment. Large quantities are consumed each year as an essential component in generators, transformers, radios, television sets, radar, electric lighting equipment, and electrical appliances. The nature, structural imperfections, and impurities determine to a great degree the usefulness of sheet mica. Proper processing and classification add greatly to its market value. This report is designed to assist producers in understanding the complexities of marketing muscovite sheet mica.

ACKNOWLEDGMENTS

Special acknowledgment is due S. A. Montague, of Spruce Pine Mica Co. and G. A. Purcell, mica consultant, General Services Administration, for their critical review and many helpful suggestions in the preparation of this report.

Assistance from other industry and Government representatives is acknowledged with thanks.

MINERALOGY

Minerals of the mica group are complex hydrous potassium aluminum silicates. They often contain magnesium, ferrous iron, and fluorine, and some varieties contain sodium, lithium, chromium, titanium, barium, and manganese. The exact composition of many of the micas is not known; however, the following formulas show the approximate compositions of the typical species in the mica group:

Species	General formula[1/]
Muscovite	$H_2KAl_3(SiO_4)_3$
Phlogopite	$H_2KMg_3Al(SiO_4)_3$
Biotite	$H_2K(Mg, Fe)_3Al(SiO_4)_3$
Lepidolite	$(OH, F)_2KLiAl_2Si_3O_{10}$
Lepidomelane	$HK_2F_3{}^{II}Fe_6{}^{III}Al_3(SiO_4)_9$
Paragonite	$H_2NaAl_3(SiO_4)_3$
Roscoelite	$H_8K(Mg, Fe)(Al, V)_4(SiO_3)_{12}$
Zinnwaldite	$(K, Li)_3FeAl_3Si_5O_{16}(OH, F)_2$

1/ Slight differences in composition give rise to numerous varieties.

A chemical analysis of mica is not significant because analyses can vary widely and usually bear little relation to the electrical or physical properties.

The micas crystallize in the monoclinic system and usually are orthorhombic or hexagonal in symmetry. All species are characterized by almost perfect basal cleavage, which permits splitting into thin sheets or laminae. Of the five commercial micas, muscovite, phlogopite, and biotite are used because of their physical properties, and lepidolite and roscoelite are mined for their lithium and vanadium content. Muscovite, the potash mica, is the major mica mineral produced in the United States and is of strategic importance. Discussion of mica in this report is limited to muscovite sheet mica.

Muscovite has an eminent basal cleavage and a secondary cleavage, which cuts the crystals at angles of 60° to 70° with the basic cleavage. The secondary cleavage may extend entirely through the crystal or only part of the way, either across the cleavage face or through the thickness of the crystal. Mica showing a secondary cleavage is called ruled mica. Owing to its basal cleavage, muscovite can be split into thin sheets or laminae less than one thousandth of an inch thick. The sheets are tough, elastic, transparent, flexible, and colorless when split to less than one-thirty-second of an inch. Thicker sheets may be colorless, pinkish buff, drab, brown, green, or red. Muscovite mica ranges in hardness from 2 to 2.5 on Mohs' scale, and has a specific gravity of 2.76 to 3 and a vitreous luster. It is insoluble in acids and will resist decomposition up to 400° C. At 700° C. it loses about one-tenth of 1 percent of its weight.

PHYSICAL DEFECTS

Structural Imperfections

Structural imperfections determine to a great degree the commercial usefulness of sheet mica. Reasonable flatness is of fundamental importance in sheet mica, but mica that is optically flat is extremely rare. Reeves, warping, wedging, and ruling are terms for imperfections that prevent flatness.

Reeves, also known as cross-grains, are lines, striations, corrugations, or folds arising from innumerable partings across the basal cleavage. Reeves can be simple, closely spaced folds or complex, broadly spaced corrugations. If the distance between the lines or the space between the missing laminae is small (narrow), the reeves appear as fine lines; if laminae are missing over a greater space, reeves are a combination of corrugations and edges of incomplete laminae. "A" mica contains two series of rulings or striations intersecting at an angle of about 60°. The third series of striations necessary to form the letter A are not present, and the intersecting reeves form a V. Typical "A" mica will have the reeves extending across the entire sheet and the apex near one edge. The area between the rulings of the "A" is frequently of good physical quality. Herringbones (fishbones, fishbacks, horsetails, or feathers) are numerous reeves that intersect to form a series of V's, the legs making an angle of 120° at the apex. These reeves usually flank a central reeve to form a pattern resembling a fish skeleton.

Buckles, waves, and ridges are terms used to describe the degree of warping. A buckle is a single concave depression in the middle of the sheet; waves are a series of alternate elevations and depressions; and ridges or ribs are parallel crenulations in the form of steps.

Wedge mica is, as the name implies, wedge-shaped and, on splitting, yields pieces of mica thicker on one side than the other. This structure is caused by the interlayering of laminae of unequal size. Wedge mica commonly has "A" or herring-bone imperfections and is referred to as "wedge-A" compared to "flat-A." Wedge mica is not satisfactory for use as sheet mica and usually can be used only as scrap mica.

Ruled or ribboned mica has parallel fractures or parting planes intersecting the basal cleavage plane at about 60°. These planes cause the mica to break into narrow strips. Books of mica can have one or more sets of fracture planes, which may pass completely or only partly through the mica.

Irregular visible cracks in the mica caused by nature or by blasting and rough handling often are present. Haircracks (hairline cracks) are minute cracks that rarely are noticeable until the mica is split and then they cause torn laminae or films.

The name tangle-sheet is applied to mica having intergrowths of individual laminae. Part of this mica often splits well; other parts will tear.

Impurities

The presence of visible mineral and vegetable impurities decreases the value of the mica. The most common imperfections resulting from impurities are stains impregnating the crystals along their cleavage planes. Staining may be caused by air bubbles, clay, iron and manganese compounds, organic matter, or a combination of two or more of these impurities in the form of specks or patches restricted to one part of the sheet or extending over the entire surface. Stains are either intergrowths and inclusions between the laminae or impurities contained in the crystal structure. Infiltrated stains can be removed by careful splitting or trimming, but there is no known method for removing crystallized stains. Mineral stains may be black, red, brown, or green, and stains caused by organic matter, commonly called vegetable stains may be yellow, green, or brown. Inclusions are of either mineral or gaseous origin. Air inclusions appear as small bubbles in clusters or pockets. When viewed by reflected light air stains appear silvery in color; when viewed by transmitted light they appear grayish. Mineral inclusions are usually dark, and some of the minerals that may penetrate the mica sheets are albite, beryl, biotite, columbite, fluorite, garnet, hematite, quartz, rutile, topaz, and tourmaline.

Stains are not the sole criteria for classifying sheet mica into quality groups, such as, Good Stained, Stained, etc. Other impurities and structural imperfections, as shown in table 3, determine the quality groups.

PREPARATION

Preparation of sheet mica for market depends solely on hand methods and human judgment. Minor imperfections, inclusions, rough edges, and defective laminae are removed by cobbing, rifting, and trimming. Quality and grade usually are judged visually. Man is limited in his efforts to improve the quality and grade of mica and nature is the controlling factor.

Preparation of sheet mica for market consists of (1) cobbing, (2) rifting, (3) trimming, and (4) classifying as to quality and grade (size).

As obtained from the mine, crude mica is in the form of crystals or rough books of various shapes and sizes and is known as mine run, run-of-mine, book, or block mica. The term "block" normally is used for prepared mica and should not be considered as a term for crude mica directly from the mine. The rough books are first cobbed to remove all adhering rock, dirt, and crushed mica. During cobbing, defective mica is segregated from the books that will yield usable sheet mica. The resultant usable rough mica is called hand-cobbed mica.

The hand-cobbed mica next is rifted or split. A straight-bladed knife usually is used in the United States for rifting. The products of the rifting operation are broadly classified as untrimmed sheet mica and scrap mica.

Basically, sheet mica is any mica that is relatively flat and free enough from physical defects to enable it to be punched or stamped into specified shapes. More specifically, sheet mica is classified as block, film, and splittings, based on the thickness and quality of the mica. Block mica is mica not less than 0.007 inch thick with a minimum usable area of 1 square inch. Film mica is split from the better qualities of block mica to a specified range of thicknesses, such as 0.00125 to 0.002, 0.002 to 0.003, and 0.003 to 0.004 inch. Splittings are sheets with a maximum thickness of 0.0012 inch. Mica 0.002 to 0.004 inch thick is called thins and 0.004 to 0.007 is called thick thins. Small sized, low-quality block mica is subdivided as punch, circle, and washer. Punch mica is thumb-trimmed material sufficient in area to yield a circular disk at least 1-1/2 inches in diameter for Stained quality mica and 1-1/4 to about 2 inches for Clear quality. Circle mica is an old term for mica larger than punch that yields sheets about 2 inches in diameter. Miners often sorted out a class of mica ranging between punch and a 1-1/2- by 2-inch grade that was known as circle or toaster mica. The poorer lots of punch mica often are referred to as washer mica. Usually, the term "punch mica" is used to include punch, circle, and washer mica.

Trimming, the next step in processing block and film mica, removes broken and ragged edges, loose scales, and any other major imperfections. Trimming may be done using a knife, sickle, shears, or fingers. In the United States, trimming usually is done with a single 3-inch blade linoleum knife to produce a beveled-edged cut. The trimmer trys to follow the natural contour of the mica. If ragged edges of the rifted mica are broken off with the thumb and fingers, it is called thumb-trimmed mica. Half-trimmed mica is rifted mica trimmed on two adjacent sides, with at least two-thirds of the mica trimmed and no cracks extending into the usable area. Full-trimmed mica is rifted mica trimmed on all sides with all cracks, reeves, and cross grains removed.

Large quantities of apparently usable high-quality, large sheet mica are ruined by improper rifting and over trimming. Care should be taken in rifting and trimming to determine what parts of the mica should be removed to obtain the maximum usable area and minimum waste. In normal times domestic producers can only thumb trim or half trim mica because the labor costs for a better trim are excessive. Every attempt should be made to obtain as good a trim as possible because the better the trim, the better the price that will be obtained. Frequently, however, the miner will find that he can obtain a greater return by selling rough-trimmed or half-trimmed mica because the greater weight more than offsets the higher price per pound for better prepared mica. Essentially, it has been profitable only to full-trim mica for sale to the Government. It takes experienced rifters and trimmers to obtain the proper yield from mine-run mica and an inexperienced worker can ruin the usable mica sheet. An experienced worker will salvage punch and even block from material that less experienced workers would discard. However, regardless of the

method used or the precautions taken, sizable quantities of scrap (referred to as bench-scrap or trimming-shop scrap) are produced.

Classification

No mineral is as difficult to classify as mica or approaches the multiplicity of qualities and grades (sizes) into which mica is classified. The best overall standard for block and film mica is American Society for Testing Materials Specifications (ASTM) D 351-53T; the best for splittings is National Electrical Manufacturers Associations Standards.

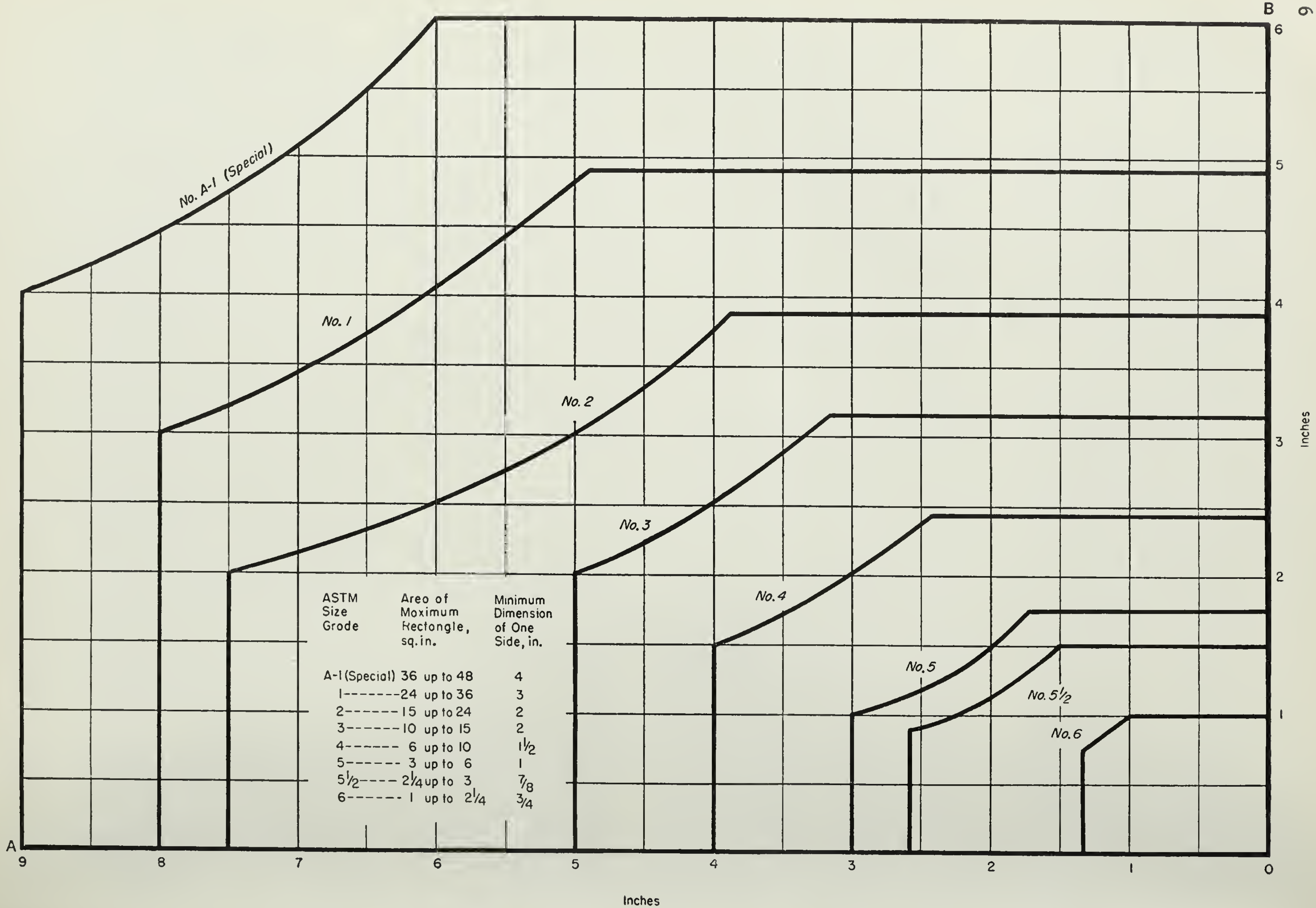
Grading

Trimming produces block or film mica of irregular shapes and sizes, and the mica must be classified according to grade (size). A standard grading system for trimmed muscovite block or film mica is based on the maximum usable rectangle that can be punched or stamped from the piece of mica. Grades are universal, but several countries use different designations, as shown in table 1. Using ASTM specifications, block and film mica can be classed into 12 grades, ranging from the smallest, No. 6, to the largest, OOEE Special. Figure 1 can be used for grading mica. The mica to be graded can be placed upon the chart so that it covers point O and has its maximum and minimum dimensions along the lines OA and OB. The specimen should be moved until the usable area completely covers the largest rectangle, as determined by an imaginary diagonal line extending from O to any point on any of the curves. The number of the curve, such as No. 4, in which the diagonal of the rectangle terminates will represent the grade number. Four grades larger than those shown in figure 1 are listed in table 1.

TABLE 1. - Grades (sizes) of muscovite block and film mica

Area of minimum rectangle, square inches	Grade (size) classification					Minimum dimensions on one side, inches
	ASTM	United States, domestically produced mica	Madagascar	India	Brazil	
100	OOEE Special	8 x 12	0000	OOEE Special	OEE Special	4
80	OEE Special	8 x 10	000	OEE Special	EE Special	4
60	EE Special	6 x 10	00	EE Special	E Special	4
48	E Special	6 x 8	0	E Special	Special	4
36	A1 Special	6 x 6	A1	Special	A1	3-1/2
24	1	4 x 6	1	1	1	3
15	2	3 x 5	2	2	2	2
10	3	3x3 & 3x4	3	3	3	2
6	4	2 x 3	4	4	4	1-1/2
3	5	1-1/2x2 & 2x2	5	5	5	1
2-1/4	5-1/2	Circle	6	5-1/2	5-1/2	7/8
1	6	Punch	6	6	6	3/4

Virtually no mica splittings are produced in the United States. Grades for mica splittings are determined by the area of usable rectangle and minimum dimension of one side of a rectangle. In accordance with NEMA Standards for Manufactured Electrical Mica, as shown in table 2, book form and loose form splittings comprise 3 grade categories, and loose with powder form comprises 4 grades.



ASTM Size Grade	Area of Maximum Rectangle, sq. in.	Minimum Dimension of One Side, in.
A-1 (Special)	36 up to 48	4
1 -------	24 up to 36	3
2 -------	15 up to 24	2
3 -------	10 up to 15	2
4 -------	6 up to 10	1½
5 -------	3 up to 6	1
5½ ----	2¼ up to 3	⅞
6 -------	1 up to 2¼	¾

Figure 1. - ASTM chart for grading natural muscovite block and film mica.

TABLE 2. - Classification of muscovite splittings[1/]

NEMA grade	Form[2/]	Size,[3/] sq. in.	Minimum dimension of usable rectangle, in.	Thickness per 10 splittings, in.	Remarks
AA...	Book form (1)..	6 up to 10	1-1/2	0.006 to 0.009 incl.	(1) Splittings shall be sound, clean, and free of mineral spots. Not more than an average of 1 in 500 splittings shall be vegetable stained. They shall be split to the specified thickness without thick edges. The edges shall be clean cut.
	Loose with powder (2)....	6 up to 10	1-1/2	.006 to .009 incl.	
A....	Book form (1)..	3 up to 6	1	.006 to .009 incl.	
	Loose with powder (2)....	3 up to 6	1	.006 to .009 incl.	
B-1..	Book form (1)..	2 up to 3	7/8	.006 to .009 incl.	
B-2..	Loose with powder (2)....	1-1/2 up to 3	7/8	.007 to .010 incl.	
C....	Loose with powder (2)....	1 up to 1-1/2	3/4	.007 to .010 incl.	
D....	Loose (2)......	At least 70 percent shall be 1 up to 1-1/2. The balance shall pass over a screen having 3/4-inch square openings.	-	.007 to .010 incl.	(2) Same as (1) except that the edges may be slightly irregular in shape. Not more than 5 percent of the splittings shall be slightly weathered or vegetable stained. None of the splittings shall have mineral stains.
E....	Loose (2)......	At least 50 percent shall be 1 up to 1-1/2. The balance shall pass over a screen having 5/8-inch square openings.	-	.007 to .011 incl.	
F....	Loose (3)......	At least 80 percent shall have a minimum area of 3/4 sq. in. and shall pass over a screen having 5/8-inch square openings.	-	.007 to .011 incl.	(3) Splittings shall be sound and clean. They shall be split to the specified thickness. Not more than 7-1/2 percent of the splittings shall be slightly weathered or vegetable stained. None of the splittings shall have mineral stains

1/ This classification is reproduced from American Society for Testing Materials Specification D 351-53T as adapted from Publication No. ME1-1952, Standards for Manufactured Electrical Mica, National Electrical Manufacturers Association.

2/ The numbers in parentheses refer to the correspondingly numbered remarks.

3/ "Up to" means "not including." Splittings shall not be all of the minimum size, but shall contain a fair proportion of sizes throughout the range specified. The size areas specified do not refer to the total area but to the rectangular size that each grade shall produce. For example, Grade A should be large enough to provide rectangular pieces measuring 1-1/2 by 2, 2 by 2, 2 by 2-1/3, ... etc., inches.

Qualifying

The quality of natural muscovite sheet mica usually is qualified visually. Interpretation of visual standards depends solely on the human eye and personal judgment and may vary from one observer to another. Visual classification is based upon the relative quantity of visible inclusions, such as air bubbles, stains, etc., and of structural imperfections contained in a piece of mica. Clear mica, which is hard, uniform in color , nearly flat, and free from all stains and other defects is the finest quality of mica. Increasing quantities of visual defects in the mica lowers the quality. In accordance with ASTM Specifications D 351-53T, based on the Bengal India system and shown in table 3, block mica falls into 11 quality groups, ranging from the poorest, Densely Stained,to the best, Clear. A verbal description for each of the 11 qualities, quoted from ASTM D 351-53T, is as follows:

V-1, Clear. - Hard, of uniform color, flat, free from all stains and foreign inclusions, waves, cracks, buckles, and other similar defects.

V-2, Clear and Slightly Stained. - Hard, of uniform color, fairly flat, free from all vegetable and mineral stains, cracks, buckles, and other similar defects and of foreign inclusions, except for a few tiny air inclusions is not more than one-fourth of the usable area.

V-3, Fair Stained. - Hard, of uniform color, free from all vegetable and mineral stains, cracks, buckles and other similar defects and of foreign inclusions, except may be slightly wavy and may contain slight air inclusions in not more than one-half of the usable area.

V-4, Good Stained. - Hard, free from vegetable or mineral stains, cracks, buckles, and other similar defects and of foreign inclusions, except may be somewhat wavy but not rippled and may contain medium air inclusions in not more than two-thirds of the usable area but may not have heavily concentrated air inclusions in any of the usable area.

V-5, Stained A. - Hard, free from cracks and other similar defects and foreign inclusions, except may be wavy with slight buckles and may contain medium vegetable stains, and the entire area may have air inclusions if not heavily concentrated.

V-6, Stained B. - Hard, free from cracks and other similar defects and foreign inclusions, except may be wavy and slightly buckled and may contain heavy air inclusions, medium vegetable, clay, and mineral stains.

V-7, Heavily Stained. - Hard, free from cracks or other similar defects and foreign inclusions, except may be wavy and buckled and may contain heavy air inclusions, heavy vegetable and medium mineral stains.

V-8, Black Dotted. - Same as Heavily Stained, except may contain black dots.

V-9, Black Spotted. - Hard, free of cracks or similar defects and foreign inclusions, except may be medium wavy and contain slight buckles and vegetable stains, black- or red-spotted mineral stains, and heavy air inclusions.

V-10, Black Stained. - V-9 quality, except may be soft and have black lines and/ or short red bars or connected stains.

V-11, Densely Stained. - Soft, and may contain all heavy stains and inclusions and other defects, heavy waves, cracks, and buckles.

TABLE 3. - Quality classification of muscovite block mica 0.007-inch minimum thickness, based on visual properties1/

ASTM visual quality classification	Clear-uniform basic color[h]	Air inclusions				Smokey stains	Light dots (mineral)	Sooty stains (mineral)	Black stains (mineral)[e]	Black stains (mineral)[g]	Red stains (mineral)[e]	Green stains (vegetable type)[f]	Clay stains	Waviness				Hard-ness		Stones	Buckles	Reeves	Ridges	Tears	Cracks	Hairlines	Wedge	Tangle sheet	Herringbones	Ribboned or ruled
		Very slight[a]	Slight[b]	Medium[c]	Heavy[d]									Nearly flat	Slight	Medium	Heavy	Hard	Soft											
V-1, clear...........	√	x	x	x	x	x	x	x	x	x	x	x	x	√	x	x	x	√	x	x	x	x	x	x	x	x	x	x	x	x
V-2, clear and slightly stained....	√	√	x	x	x	x	x	x	x	x	x	x	x	√	x	x	x	√	x	x	x	x	x	x	x	x	x	x	x	x
V-3, fair stained	√	√	√	x	x	x	x	x	x	x	x	x	x	√	√	x	x	√	x	x	x	x	x	x	x	x	x	x	x	x
V-4, good stained	√	√	√	√	x	x	x	x	x	x	x	x	x	√	√	√	x	√	x	x	x	x	x	x	x	x	x	x	x	x
V-5, stained A	√	√	√	√	√	√	x	x	x	x	x	√	x	√	√	√	√	√	x	x	x	x	x	x	x	x	x	x	x	x
V-6, stained B	√	√	√	√	√	√	x	x	√	x	√	√	√	√	√	√	√	√	x	x	√	x	x	x	x	x	x	x	x	x
V-7, heavy stained ...	√	√	√	√	√	√	x	x	√	x	√	√	√	√	√	√	√	√	S	x	√	x	√	x	x	x	x	x	x	x
V-8, black dotted	√	√	√	√	√	√	x	x	√	x	√	√	√	√	√	√	√	√	S	x	√	x	√	x	x	x	x	x	x	x
V-9, black spotted ...	√	√	√	√	√	√	√	√	√	x	√	√	√	√	√	√	√	√	S	x	√	√	√	x	x	x	x	x	x	x
V-10, black stained...	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	S	√	√	√	√	√	√	√	√	x	√	√
V-11, densely stained.	√	√	√	√	√	√	√	√	√	x	x	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

Symbols:
√ - Permissible.
x - Not permissible.
S - Permissible only if specified.

[a] Few and tiny in 1/4 of useable area.
[b] In 1/2 useable area.
[c] In 2/3 useable area.
[d] Uniformly distributed.
[e] Slight.
[f] Medium.
[g] Heavy.
[h] Crystallographic discoloration is permitted to a limited extent in V-4 Good Stained quality. It is not permitted in qualities higher than V-4 Good Stained. In qualities below V-4 Good Stained it is permitted without limit.

Note 1. - The visual properties of block mica usually are judged under the following light conditions:
For stains and inclusions. - Transmitted daylight or equivalent.
For air inclusions. - Reflected daylight or equivalent.
For waves, buckles, ridges, etc. - Reflected daylight or equivalent where distortion of parallel and vertical lines of reflected image such as a window frame can be judged.
Note 2. - The hardness or mechanical properties of block mica are usually judged by a sharp, clear ring when mica is dropped on a hard surface.
Note 3. - Muscovite mica occurs in various colors which are more pronounced the thicker the block. Some typical colors are ruby, white, light green, rum, etc.
Note 4. - Cracks, tears, stones, or pin holes are judged by transmitted daylight or equivalent.
Note 5. - Rigidity is judged by the relative stiffness when flexing with the fingers.
1/ Source - American Society for Testing Materials.

Muscovite film mica is classified into three quality designations. First-quality film is equivalent in visual quality to Fair Stained block mica. Second quality is comparable to mica split from Good Stained block mica, while Third quality is equivalent to Stained quality block.

American Society for Testing Materials is preparing standard mica samples as an aid for a more uniform quality classification. A committee has agreed upon the samples and is attempting to eliminate duplication and minimize the number of specimens in each quality category. After the commingled samples are completed, they will be sent to ASTM headquarters at Philadelphia, Pa., and will be available for comparison. ASTM also is investigating costs and means of supplying duplicate sets.

Much foreign block and film mica is sold to industry according to quality groups that deviate somewhat from the quality nomenclature of ASTM. The prime difference between respective qualities is that a greater percentage of defects can be present than are permitted by ASTM specifications. While this usually is referred to as a commercial quality system, it has no exact standard except that the quality groups are based on ASTM specifications and respective qualities will vary from company to company.

The small domestic miner usually does not have the experience to appraise the mica for quality in accordance with ASTM standards. It has been customary in the United States during normal times for the miner to sell thumb-trimmed or half-trimmed block mica and qualify an entire lot of mica in a rough manner. Domestic block mica, including punch mica, is classified into two primary groups - Clear and Stained. Clear mica is subdivided into No. 1, No. 2, and No. 2 inferior. Black-Stained and Spotted mica is known as No. 3, electric, or stained. An approximate comparison between the domestic quality classification and ASTM standards is as follows:

Domestic	ASTM
No. 1	Clear, and Clear and Slightly Stained Fair Stained
No. 2	Good Stained
No. 2 inferior	Stained Heavy Stained
No. 3 (electric or stained)	Black Spotted Black Stained

A miner usually can sell sheet mica to industry without qualifying or grading the mica by selling it as mine-run mica. Many of the lots of domestic sheet mica sold to industry are of such small quantity that it is not worthwhile for the miner to classify the mica.

In recent years, attention has been given to classifying mica in terms of its electrical properties. The American Society for Testing Materials has adopted standard methods for testing the dielectric strength, power factor, and electrical conductivity of mica, as outlined in ASTM Designation D 748-52T. Natural block and film mica based upon its "Q" value or power factor can be divided into three groups. Group E-1 has a minimum Q value of 2,500 at 1 megacycle; E-2, a minimum of 1,500; and E-3, a minimum of 200. The Q value is the reciprocal of the power factor, which is a measure, expressed in percent, of electrical energy loss. A more conclusive

classification, using the electrical ratings, physical properties, and structural imperfections, in accordance with ASTM D 748-52T, divides block and film mica into classes C-1, C-2, and C-3. Class C-1 block and film mica has the highest Q value, a minimum of 2,500 at 1 megacycle (E-1 rating). Mica in this class is usable in all types of silver and foil electrode molded and clamped capacitors, including those used in high-stability tuned circuits, and high-current radio frequency transmitter circuits. Class C-2 mica has a minimum Q value of 1,500 and can be used in all silver and foil electrode, molded and clamped unit capacitors. However, some of the capacitors made from C-2 block and film mica may show a higher temperature rise for transmitter use than similar capacitors made with C-1 mica. Lowest Q value mica (minimum 200) falls in Class C-3 and is applicable in foil electrode molded and clamped capacitors where high stability and low-temperature coefficient are not required.

Suffix letters are used after the class designation to indicate the degree of air inclusions and waviness. Thus, a mica classed as C-1-BA would be of the highest electrical quality (C-1) with medium air inclusions (B) and flat to slightly wavy (A) (table 4). Class C-1-AA is equivalent to Fair Stained block or First quality film; C-1-BB, Good Stained block or Second quality film; and C-1-CC, Stained block and Third quality film.

Included in the test methods of Specification D 748-52T is a spark coil test for determining electrical conductivity of the mica. Certain mineral inclusions, particularly iron oxides, increase the conductivity and make the mica less desirable. Electrical conductivity in spotted and stained areas is revealed when the high-voltage spark glows.

Classification by electrical properties supplements the visual inspection system but does not eliminate mica containing some visual imperfections and inclusions if the mica passes the electrical requirements for conductivity and "Q." It has been found that sizable quantities rejected solely on the basis of visual classification are usable when tested by the "Q" meter and spark coil. Although this could result in a saving of mica, industry has been reluctant to replace visual inspection with electrical testing because of the economic factors involved in the segregation and testing of a large quantity of low-quality mica to obtain the relatively small quantity that may be found usable.

Color

Sheet mica also is classified according to color. Mica occurs in many colors, ranging from green through shades of green and brown to pinkish buff and drab. The Federal Geological Survey has arranged muscovite mica into seven main color categories and three commercial groups, as shown below:

Main color categories	Commercial groups
Pinkish buff and drab Cinnamon brown Brown	Ruby
Brown Brownish olive Yellowish olive	Rum
Yellowish olive Yellowish green Green	Green

TABLE 4. - Electrical, physical, and visual quality requirements of natural block and film mica for use in capacitors1/

	Class C-1	Class C-2	Class C-3
Electrical properties:			
Conductivity[g]	None	None	None
Q value or power factor at 1 megacycle	E-1[a]	E-2[a]	E-3[a]
Dielectric strength, v. per mil at 60 cycles per sec., min., average	1,000	1,000	1,000
Dielectric strength, v. per mil at 60 cycles per sec., min., single	850	850	850
Dielectric constant	b	b	b
Physical properties:			
Weight loss on heating (5 min. at 600° C.) max., percent	0.2	0.2	
Thickness uniformity (mica films)[c]	Best	Best	Intermediate
Temperature coefficient of capacitance and retrace	d	d	d
Visual qualities:			
Air inclusions[e] A	None to slight	None to slight	None to slight
Air inclusions[e] B	Medium	Medium	Medium
Air inclusions[e] C	Medium to heavy	Medium to heavy	Medium to heavy
Waves[f] A	Flat to slight	Flat to slight	Flat to slight
Waves[f] B	Medium	Medium	Medium
Waves[f] C	Medium to heavy	Medium to heavy	Medium to heavy
Cracks	None	None	None
Tears	do.	do.	Do.
Pin holes	do.	do.	Do.
Stones	do.	do.	Do.
Buckles	do.	do.	Do.
Ridges	do.	do.	Do.

[a]The Q value or power factor $(Q = \frac{1}{\text{power factor}})$ of block mica or mica films suitable for use in capacitors shall fall within the 3 electrical quality groups, based on end-use requirements, designated E-1 Special, E-1, E-2, or E-3. These quality groups shall conform to the Q or power factor values prescribed in Table III of ASTM D 748-52T or the corresponding scale readings of the vacuum-tube voltmeter when tested by the rapid, direct-reading method described in Appendix I, of ASTM D 748-52T.

[b]As the dielectric constant of natural block mica suitable for use in capacitors is fairly uniform, no specified requirement is needed.

[c]Until definite values can be specified, the permissible amounts of such defects shall be agreed upon by the purchaser and the manufacturer.

[d]It has been found that the temperature coefficient of capacitance and retrace of capacitors made with Classes C-1, C-2, and C-3 mica depend more on such factors as electrical and mechanical design and manufacturing technique than any differences that may be attributed to the mica itself.

[e]The amount of air inclusions shall not exceed the specified limits for each subclass as judged by the photographic reference standards[5] shown in figs. 1 to 3 of ASTM D 748-52T. The permissible amount of air inclusions shall be stated by suffixing the letter A, B, or C, as the case may be, to the required electrical quality class.

[f]Until definite values can be specified, the permissible amount of waves, buckles, and ridges shall be agreed upon by the purchaser and the manufacturer. The permissible amount of waves shall be stated by suffixing the letter A, B, or C, as the case may be,to the letter denoting the amount of permissible air inclusions, for example: Class C1 B A block mica or mica films denotes:

C-1	B	A
Best electrical quality	Medium air inclusions	Flat to slight waves

[g]This applies to the conductivity of visible spots and stains only and excludes "air stains or air inclusions."

1/ American Society for Testing Materials.

The National Bureau of Standards has established two color groups, namely ruby and nonruby. In the laboratory, hue and lightness indices are used to determine the color of the mica. Despite the many variables that effect color, industry has a definite idea of what is acceptable as ruby mica. An experienced inspector becomes familiar with the family of colors that falls in each group. Mica having a ruby color is classed as ruby, and mica appearing green or brownish, disregarding variations such as air or mineral inclusions and stained areas, is classed as nonruby. Mica for the National Stockpile is purchased on the Bureau of Standards color classification.

Ruby mica is the preferred color because its "Q" factor is fairly constant and it splits easily. Industry is reluctant to use nonruby as a substitute for ruby mica in electronic products. Nonruby has a tendency to be brittle, and its "Q" factor varies considerably and often is undesirably high. Normally, nonruby is accepted only if it passes the visual and electrical tests. For ordinary electrical uses, color is of little significance.

MARKETING

Production and Consumption

The United States is the world's largest consumer of muscovite sheet mica, but only a small part of the United States requirements is produced domestically. High labor costs in the United States and the large labor factor required to mine and process sheet mica have restricted the domestic mica industry. Historically, domestic production has been mainly punch mica. Only in times of emergency through Government subsidization have sizable quantities of sheet mica been produced domestically. Crude sheet mica production in 1953 totaled 667,241 pounds of punch mica valued at $98,010 and 182,153 pounds of sheet mica larger than punch valued at $2,055,574. North Carolina was the largest producing State for sheet mica in 1953, supplying 73 percent of the total domestic output. The remaining production came from the following States, arranged in order of importance by quantity produced: New Hampshire, Connecticut, Maine, Idaho, Virginia, Georgia, South Dakota, and Alabama. Consumption of block and film mica cut or stamped to dimension by domestic fabricators totaled 4,305,599 pounds, of which only 10 percent was from domestic mines (97 percent of this was punch mica). Distribution of consumption of block and film mica in 1953 for end-product use by quality is given in table 5. Consumption of muscovite splittings totaled 9,443,364 pounds. The electronic and electrical industries, which are so essential to the highly mechanized way of life in the United States, must rely on foreign sources for the higher quality sheet mica. India has been the principal source of muscovite sheet (block, film, and splittings). In recent years, Brazil has been an important exporter of block mica to the United States. Smaller quantities of muscovite block mica have come from Angola, Argentina, Canada, Northern and Southern Rhodesia, and Tanganyika.

Uses

Sheet mica, as single pieces split from crystals or as composite pieces in a built-up form, is an important material to the electronic and electrical industries. Block mica is used in manufacturing transmitting and receiving tubes, high-temperature steam gage glass, diaphragms, compasses, and as an insulator in electrical equipment (table 5). In the electronic field, most of the block mica is consumed as bridges and spacers in radio and television tubes. Usually more Stained quality block is used for tube manufacture than any other quality. Lower qualities of block mica, including punch mica, are used mainly as electrical insulators in household appliances such as electric irons, toasters, and water heaters; in incandescent lamps; fuse plugs; and other electrical appliances.

TABLE 5. - Fabrication of muscovite ruby and nonruby block and film mica, by quality and end-product use in the United States, 1953, in pounds

Variety, form, and quality	Electronic uses				Nonelectronic uses			Grand total
	Capacitors	Tubes	Other	Total electronic	Gage glass and diaphragms	Other	Total non-electronic	
Muscovite:								
Block:								
Good Stained or better..	1,377	126,339	4,354	132,070	7,134	10,597	17,731	149,801
Stained	9,282	1,956,917	32,043	1,998,242	1,706	150,031	151,737	2,149,979
Lower than Stained	314	540,787	32,665	573,766	1,246	1/1,184,424	1,185,670	1,759,436
Total	10,973	2,624,043	69,062	2,704,078	10,086	1/1,345,052	1,355,138	4,059,216
Film:								
First	51,954	8	-	51,962	-	2	2	51,964
Second	181,793	-	176	181,969	-	321	321	182,290
Other	12,129	-	-	12,129	-	-	-	12,129
Total	245,876	8	176	246,060	-	323	323	246,383
Block and film:								
Good Stained or better 2/..	235,124	126,347	4,530	366,001	7,134	10,920	18,054	384,055
Stained 3/................	21,411	1,956,917	32,043	2,010,371	1,706	150,031	151,737	2,162,108
Lower than Stained	314	540,787	32,665	573,766	1,246	1,184,424	1,185,670	1,759,436
Total	256,849	2,624,051	69,238	2,950,138	10,086	1,345,375	1,355,461	4,305,599

1/ Includes punch mica.
2/ Includes first and second quality film.
3/ Includes other quality film.

Film mica is used in capacitors that hold or store an electrical charge. Mica is useful in capacitors because it can be split into thin sheets, has a high dielectric constant and low power factor, is resistant to high temperatures, and can be fabricated easily. Certain capacitors, especially those used in high voltages and high frequencies can be made only from mica. Film mica for capacitors must be fairly flat, must split to close tolerances and be of the higher qualities (Stained or better).

Mica splittings are used in manufacturing built-up mica by heating, pressing, and trimming alternate layers of splittings and a binder (shellac, alkyl, or silicone resin). Products cut or stamped from sheets of built-up mica are used mainly as an insulating material in electric motors, generators, and transformers.

In peacetime, the emphasis is placed on mica usable in radio and television tubes, household appliances, heavy electrical equipment, and, to a lesser degree, capacitors. Civilian consumption requires large quantities of the lower quality sheet mica and demand for the highest qualities is not excessive. However, in times of emergency and stockpiling, demand for high-quality mica suitable for essential military applications increases tremendously. From all indications, sheet mica, especially of the higher qualities, will be in high demand for many years to come.

Buyers of Sheet Mica

Commercial buyers of block and film mica are shown in the accompanying list of mica fabricators (table 6). These buyers usually purchase both domestic and foreign mica, but in the past few years only the fabricators in North Carolina and Virginia have purchased domestic mica. Companies purchasing mica splittings are shown in the list of built-up mica producers (table 7). Importers of sheet mica are listed in table 8.

Government Mica Programs

Strategic muscovite block and film mica, according to the present concept, is ruby and nonruby block, Good Stained or better qualities, grade No. 6 and larger; ruby Stained quality, grade No. 6 and larger; and ruby and nonruby film, First and Second qualities, grade No. 4 and smaller. Strategic muscovite splittings are splittings in the book and loose dusted form, grade No. 6 and larger, and loose packed form, No. 6. Pursuant to Section 2(a) of Public Law 520, 79th Congress, mica block, film, and splittings were placed on the list of strategic and critical materials to be acquired for the National Stockpile. The Government has two mica programs - one for purchasing domestic and foreign sheet mica and the other for assisting domestic mica exploration.

TABLE 6. - Fabricators of block and film mica

Aerovox Division, Aerovox Corp., 740 Belleville Ave., New Bedford, Mass.
American Mica Insulation Co., 235 Parker Ave., Manasquan, N. J.
American Mica Products Co., 17 East 48th St., New York 17, N. Y.
Asheville Mica Co., P. O. Box 318, Newport News, Va.
The B G Corp., 321 Broad Ave., Ridgefield, N. J.
Carpenter & Phillips Mica Co., P. O. Box 657, Spruce Pine, N. C.
Cornel-Dublier Electric Corp., 55 Cromwell St., Providence 7, R. I.
Diamond Power Speciality Corp., P. O. Box 415, Lancaster, Ohio
Farnam Mfg. Co., Inc., Sweeten Creek Rd., Asheville, N. C.
Ford Radio & Mica Corp., 536 - 63d St., Brooklyn 20, N. Y.
General Electric Co., 1 River Road, Schenectady 5, N. Y.
Huse-Liberty Mica Co., 171 Camden St., Boston, Mass.
Industrial Mica Corp., 223 South Van Brunt St., Englewood, N. J.
Mica Fabricating Co., 53 Central Ave., Rochelle Park, N. J.
Mica Insulator Co., 757 Broadway, Schenectady 5, N. Y.
Micacraft Products, Inc., 701 McCarter Highway, Newark 5, N. J.
Micamold Radio Corp., 1087 Flushing Ave., Brooklyn 37, N. Y.
Perfection Mica Co., 20 North Wacker Drive, Chicago, Ill.
Radio Corporation of America, Tube Div., Camden 2, N. J.
Reliance Mica Co., 341 - 39th St., Brooklyn, N. Y.
Sangamo Electric Co., Box 7, Marion, Ill.
Sprague Electric Co., Marshall St., North Adams, Mass.
Spruce Pine Mica Co. & Mayland Mfg. Co., Spruce Pine, N. C.
Sylvania Electric Products, Inc., Smethport, Pa.
The Tar Heel Mica Co., Inc., Plumtree, N. C.
Victory Mica Mfg. Co., Inc., 1313 - 39th St., Brooklyn 18, N. Y.
Vulcan Electric Co., Div. of Consolidated Electric Lamp Co., 88 Holton St., Danvers, Mass.
Western Electric Co., Inc., 195 Broadway, New York 7, N. Y.

TABLE 7. - Producers of built-up mica

(Consumers of mica splittings)

Allis-Chalmers Mfg. Co., Box 512, Milwaukee 1, Wis.
American Electrical Heater Co., 6110 Cass Ave., Detroit, Mich.
Cleveland Mica Co., 1360 Hird St., Lakewood, Ohio
Continental-Diamond Fibre Co., Valparaiso, Ind.
General Electric Co., 920 Western Ave., West Lynn 3, Mass.
General Electric Co., 1 River Road, Schenectady, N. Y.
General Electric Co., 2901 East Lake Road, Erie, Pa.
The Macallen Co., Bay Road, Newmarket, N. H.
Mica Company of Canada, 900 Jefferson Ave., Newport News, Va.
Mica Insulator Co., 757 Broadway, Schenectady 5, N. Y.
National Electric Coil Co., Columbus 16, Ohio
New England Mica Co., Inc., 66 Woerd Ave., Waltham, Mass.
The Tar Heel Mica Co., Inc., Plumtree, N. C.
Westinghouse Electric Corp., 306 Fourth Ave., Pittsburgh 30, Pa.

TABLE 8. - Importers of sheet mica

American Mica Insulation Co., 235 Parker Ave., Manasquan, N. J.
Ameritex Development Corp., 37 Wall St., New York, N. Y.
Asheville-Schoonmaker Mica Co., Inc., 62 Worth St., New York, N. Y.
Associated Commodity Corp., 150 Broadway, New York 38, N. Y.
Blanchard Mica, Inc., 2315 Broadway, New York 24, N. Y.
BMT Commodity Corp., 233 Broadway, New York 7, N. Y.
Brand Dielectrics, Inc., 57 North St., Willimantic, Conn.
Brown, Alfred D. Associates, Inc., 59 Pearl St., New York 4, N. Y.
Buck, Leonard J., Inc., 1 Newark Ave., Jersey City 2, N. J.
Crystals, S. A., 214 East 18th St., New York 3, N. Y.
Federal Export & Import Cos., 92 Liberty St., New York 6, N. Y.
Ferrotrader (Canada), Inc., 265 Craig St., Montreal, Quebec
Frazar & Co., Inc., 50 Church St., New York 7, N. Y.
Ford Radio & Mica Corp., 536 - 63d St., Brooklyn 20, N. Y.
Garneau Mica Co., Inc., 11 Park Place, New York, N. Y.
Gillespie-Rogers-Pyatt Co., Inc., 75 West St., New York 6, N. Y.
Haber's Export Agencies, Inc., 45 N. Broad St., Ridgewood, N. J.
Hal Dalphin & Co., 880 Bergen Ave., Jersey City 7, N. J.
The India Mica Co., 105-37 - 86th St., Ozone Park 17, New York, N. Y.
Inter-Ocean Trade Co., 48 West 48th St., New York 36, N. Y.
Lager, Andrew & Co., Inc., 150 Broadway, New York 38, N. Y.
Madagascar Graphite & Mica Co., 92 Liberty St., New York 6, N. Y.
Manchard Trading Corp., 2315 Broadway, New York 24, N. Y.
Minerals & Insulation Co., 53 Central Ave., Rochelle Park, N. J.
Munsell, Eugene & Co., 34 Exchange Place, Jersey City, N. J.
National & Foreign Trade Corp., 38 Pearl St., New York, N. Y.
The Otto Gerdau Co., 82 Wall St., New York 5, N. Y.
Paquet, M. & Co., Inc., 17 Battery Place, New York 4, N. Y.
Pitts, F. D., Co., 85 Chestnut Hill Road, Newton 67, Mass.
Rector Mineral Trading Corp., 551 Fifth Ave., New York 17, N. Y.
Schwab Brothers Corp., 102 Maiden Lane, New York 5, N. Y.
Sigbert Loeb, 120 Libert St., New York 6, N. Y.
Silvio Gaguine & Co., 154 Nassau St., New York City, N. Y.
Strygler, H. S., & Co., 665 Fifth Ave., New York 22, N. Y.
Suhr & Budelman, Inc., 97 State St., Westbury, Long Island, N. Y.
Superior Mica & Mineral Supply Corp., 174 North Franklin St., Hempstead, Long Island, N. Y.
Sylvania Electric Products, Inc., 1740 Broadway, New York 19, N. Y.
Trans American Mercantile Corp., 120 West 42d St., New York 36, N. Y.
United Mineral & Chemical Corp., 16 Hudson St., New York 13, N. Y.
Western Hemisphere Raw Materials Co., 1 Newark Ave., Jersey City, N. J.
Whittaker, Clark & Daniels, Inc., 260 West Broadway, New York 13, N. Y.

In 1952, the United States Government authorized, through General Services Administration (GSA), purchasing programs for sheet mica mined within the United States. Program A is for the purchase of muscovite ruby and nonruby block and film mica and Program B for ruby and nonruby hand-cobbed mica. Both programs are to be in effect until June 30, 1957 or when the total block, film, and hand-cobbed mica delivered to and accepted by the Government reaches the equivalent of 25,000 short tons of hand-cobbed mica (90 pounds of block and film mica are equivalent to 1 ton of hand-cobbed mica). All muscovite block and film mica purchased under Program A must conform to the appropriate requirements for grade, quality, and thickness in accordance with ASTM Specifications D 351, latest revision as of date of acceptance

for each lot. Nonruby block and film mica of Good Stained or better qualities also must meet requirements for Class C-1-BB of ASTM Specifications D 748, latest revision as of date of acceptance of each lot. Block and film mica is purchased in three quality groups - Good Stained or better, Stained, and Heavy Stained - and in three grade groups - Nos. 5-1/2 and 6, Nos. 4 and 5, and Nos. 3 and larger. All Good Stained or better block and film must be full-trimmed, but Stained and Heavy Stained is accepted as full-trimmed or half-trimmed. Hand-cobbed mica purchased under Program B must yield at least 40.5 pounds of full-trimmed block or film mica, Stained or better qualities, per short ton, when processed by the depot. Block and film mica processed from hand-cobbed mica must conform to the requirements of Program A regarding grade, quality, and thickness.

Purchasing depots are at Spruce Pine, N. C.; Franklin, N. H.; and Custer, S. Dak. Mica should be delivered f. o. b. the nearest depot, with each lot containing either ruby or nonruby mica. Mixed lots are not accepted. Any person wishing to participate in either program should notify the Regional Director, GSA, having jurisdiction over the nearest depot or the superintendent of the depot. Such notice should state that the applicant has read the mica regulations (Title 32A - National Defense, Appendix, Chapter XIV, General Services Administration, Mica Regulation: Purchase Programs for Domestic Mica), state he accepts the terms and conditions, and indicate the program in which he desires to participate. The superintendent of the respective depot will notify the participant of a delivery date. Each mica delivery is inspected at the depot, and any mica not conforming to the minimum requirements is rejected, with all costs except inspection cost being borne by the participant. Prices for domestic mica purchased by the Government under Program A are given in table 10.

The Government also purchases muscovite block and film mica produced in foreign countries. Ruby and nonruby block mica is purchased in the full-trimmed condition, Good Stained or better quality, grade 6 and larger. Ruby block also is accepted in the Stained quality under certain conditions with a proportionate quantity of ruby Good Stained or better qualities. Half-trimmed block is purchased only for ruby of qualities lower than Good Stained. Ruby and nonruby film are acceptable as full trimmed, First and Second qualities. Each lot of block and film mica must conform to National Stockpile Material Purchase Specifications P-32a-R (block) and P-32b-R (film). These specifications incorporate ASTM Specifications D 351 and D 748.

Nonruby block and film mica also must meet requirements for Class C-1-BB of ASTM Specification D 748.

The National Stockpile objective for muscovite splittings has been reached, and no new contracts have been issued since 1951.

Foreign mica usually is bought by the Government for delivery to a GSA warehouse through Federal Supply Service, 34 Exchange Place, Jersey City, N. J.

The encouragement of exploration of unknown or undeveloped sources of strategic mica through financial assistance was established as a function of Defense Minerals Exploration Administration in 1951. Under the program, the Government advances 75 percent of the approved costs of the mica exploration project, repayable from the net returns from any mineral produced as a result of the project within 10 years after certification of discovery or development. Applications for exploration assistance may be obtained from and filed with DMEA, Department of the Interior, Washington 25, D. C., or the nearest DMEA field executive office. If the application warrants a field examination, members of a DMEA field team (usually a Federal

Bureau of Mines mining engineer and Federal Geological Survey geologist) will examine the property to determine if an exploration project is justified. In the event an application is approved, the Government will enter into an exploration contract with the applicant.

Prices

Prices offered by fabricators for domestic sheet mica range from a few cents to over $10 per pound. Quoted prices are nominal, and actual selling prices are determined by direct negotiation between buyer and seller after agreement as to quality and grade of particular lots. Prices in the North Carolina district in 1955 are shown in table 9. The range in price for each grade is caused by differences in quality, preparation, and exactness of grading.

Prices paid by the Government for domestic sheet mica under Program A are about 3 to 5 times the market price. Payment for each lot of ruby and nonruby block and film mica containing 18 percent or more Good Stained or better quality is made on the price schedule shown in table 10. Payment for any lot containing less than 18 percent Good Stained or better quality is made using the price schedule, table 10, with adjustments to account for proportions of lower quality mica.

TABLE 9. - Prices for various grades and qualities of sheet mica in North Carolina district, 1955, in dollars per pound

Grade (size)	Price per pound: Clear quality	Price per pound: Stained quality
Washer mica	$0.06 - $0.10	$0.06 - $0.10
Punch mica	.10 - .16	.10 - .16
1-1/2 x 2 inch	.70 - 1.60	-
2 x 2 inch	1.10 - 1.60	.70 - 1.10
2 x 3 inch	1.60 - 2.00	1.20 - 1.60
3 x 3 inch	1.80 - 2.30	1.40 - 1.80
3 x 4 inch	2.00 - 2.60	1.60 - 2.10
3 x 5 inch	2.60 - 3.00	1.80 - 2.70
4 x 6 inch	2.75 - 4.00	2.00 - 3.00
6 x 8 inch	4.00 - 8.00	2.25 - 3.50
8 x 10 inch	6.00 - 13.00	3.00 - 4.00

TABLE 10. - Domestic mica purchasing program (GSA) prices per pound, ruby and nonruby block and film mica

	Qualities				
	Full-trimmed			Half-trimmed	
Grades	Good Stained or better	Stained	Heavy Stained	Stained	Heavy Stained
Ruby					
No. 3 and larger	$70.00	$18.00	$13.00	$12.00	$8.00
No. 4 and No. 5	40.00	8.00	6.00	5.00	4.00
No. 5-1/2 and No. 6	15.00	5.00	3.00	3.00	2.00
Nonruby					
No. 3 and larger	70.00	14.40	10.40	9.60	6.40
No. 4 and No. 5	40.00	6.40	4.80	4.00	3.20
No. 5-1/2 and No. 6	15.00	4.00	2.40	2.40	1.60

Government prices paid for ruby or nonruby hand-cobbed mica under Program B are $600 per short ton and $540 per short ton, respectively, based on a yield of 16.2 pounds of Good Stained or better qualities and 24.3 pounds of Stained quality block or film mica per short ton. If the actual yield exceeds the preliminary estimate, the participant will be paid the difference, and if the yield is less than preliminary estimates, the amount of overpayment must be repaid to the Government.

Bureau of Mines
Information Circular 7730

NATIONAL SURVEY OF BURNER-FUEL OILS, 1955

BY O. C. BLADE

United States Department of the Interior — October 1955

NATIONAL SURVEY OF BURNER-FUEL OILS, 1955

BY O. C. BLADE

* * * * * * * * * **Information Circular 7730**

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
J. J. Forbes, Director

Work on manuscript completed August 1955. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Information Circular 7730."

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October 1955

NATIONAL SURVEY OF BURNER-FUEL OILS, 1955

by

O. C. Blade 1/

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1/ Chemist (Petroleum)

INTRODUCTION

This survey report, the first for this type of fuel, is issued to provide information on the characteristics of the burner-fuel oils now manufactured for sale. Reports of surveys of diesel fuel, conducted under a cooperative agreement between the American Petroleum Institute and the Bureau of Mines, United States Department of the Interior, have been published annually since 1950.[2] This survey of burner-fuel oils is similar to the diesel-fuel surveys in pattern and has been conducted under an extension of the same agreement at the request of the Oil-Heat Institute of America and the petroleum industry. It is not intended to conflict with the diesel-fuel survey but rather to supplement it. Burner-fuel oils, also specifically referred to as heating oil, range oil, furnace oil, "Bunker C," and fuel oil, are sold in increasing volumes for use in this country and for export. Sales of all grades of fuel oil in the United States have increased from 340 million barrels in 1926[3] to over a billion barrels per year.[4] Distillate fuel oil sales, in proportion to total fuel-oil volume sold, increased from 42 percent in 1950 to 50 percent in 1954. Sales of distillate and the heavier residual oils during recent years are shown:

Fuel-oil sales, thousands of barrels[4]

	1950	1951	1952	1953	1954[5]
Distillate fuel oil	395,306	448,908	497,210	488,844	526,245
Residual fuel oil	554,208	563,388	556,273	564,729	522,714
Total	949,514	1,012,296	1,053,483	1,053,573	1,048,959

It must be realized that the data given are not accurate indications of the use of these materials as burner fuels. Some burner fuel, used as range oil, is kerosine, which is not included above. A large volume of fuel oil--approximately 30 percent of the distillate type and some residual fuel oil--is sold as diesel fuel. Smaller

2/ Blade, O. C., National Annual Diesel-Fuel Surveys, 1950-54: Bureau of Mines Reports of Investigations 4746, 25 pp.; 4830, 1951, 12 pp.; 4935, 1952, 22 pp.; 5008, 1953, 24 pp.; 5084, 1954, 24 pp. (In cooperation with the American Petroleum Institute).

3/ Coumbe, A. T. and Avery, I. F., A Quarter Century of Fuel-Oil Sales, 1926-50: Bureau of Mines Information Circular 7630, 1952, 100 pp.

4/ Coumbe, A. T. and Avery, I. F., Sales of Fuel Oil and Kerosine in 1954. Distillate and Kerosine Sales Increase; Residual Grades Decline: Bureau of Mines Mineral Report 2412, 1955, 16 pp.

5/ Preliminary figures on demand, subject to revision.

TABLE 1.--Summary of grade 1 fuels, burner-fuel oil survey, 1955

Geographic distribution of burner-fuel oils 1/		Eastern Region			Southern region			Central region			Rocky Mountain region			Western region		
Districts within region		A,B,C			D			E,F,G			H,I,J,K			L,M,N		
Additional districts 2/		D,E,G			A,B,C,E,G			C,D,H,I,K,L			E,F,G,L,M			F,H,I,K		
Number of fuels		25			8			35			19			15		
Test	A.S.T.M.	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Gravity ° A.P.I.	D287	40.6	43.6	48.5	41.2	42.7	44.6	38.8	42.3	44.6	39.1	42.3	44.6	35.2	38.5	42.7
Flash point, Tag closed tester ° F.	D56	114	-	150	128	-	146	122	-	162	120	-	150	125	-	185
Viscosity																
Kinematic at 100° F. centistokes	D445	1.42	1.64	2.0	1.59	1.72	1.9	1.54	1.79	2.3	1.47	1.67	1.99	1.54	1.89	2.2
Cloud test ° F.	D97	-56	-	0	-44	-	< 0	-56	-	20	<-50	-	-10	-56	-	-20
Pour point do.	D97	-60	-	<0	-55	-	-35	-60	-	-10	-55	-	-20	<-60	-	<-20
Sulfur content wt. percent	D129	0.025	0.089	0.272	0.025	0.048	0.10	0.025	0.140	0.50	0.018	0.147	0.377	0.01	0.222	0.44
Aniline point ° F.	D611	143.5	151.1	168.8	146	150	152	135.9	149.6	159	135.9	145.9	155	120	139.4	155
Ramsbottom carbon residue on 10 percent residuum percent	D524	0.00	0.059	0.13	0.01	0.051	0.13	0.01	0.067	0.123	0.002	0.056	0.105	0.03	0.075	0.11
Corrosion, 3 hours at 122° F.	D130	0	-	1	0	-	1	0	-	1	0	-	1	0	-	2
Ash percent	D482	0.000	0.000	0.001	0.00	0.000	<0.001	0.000	0.000	0.004	0.00	0.000	0.001	0.00	0.000	<0.01
Water and sediment vol. percent	D96	0.00	0.00	< 0.1	0.00	0.00	< 0.1	0.00	0.00	Trace	0.00	0.00	Trace	0.00	0.00	Trace
Distillation test, on volume recovered basis:	D86															
Initial boiling point ° F.		320	341	366	332	345	366	317	347	387	317	349	382	323	350	396
10 percent		350	376	399	364	379	392	360	385	423	360	385	410	362	399	420
50 percent		397	424	462	416	427	448	416	437	464	403	431	461	410	447	466
90 percent		443	488	540	468	492	524	468	506	540	465	495	551	451	508	549
End point		496	531	576	502	527	550	502	548	585	496	545	580	487	553	586

TABLE 2.--Summary of grade 2 fuels, burner-fuel oil survey, 1955

Geographic distribution of burner-fuel oils 1/		Eastern region			Southern region			Central region			Rocky Mountain region			Western region		
Districts within region		A,B,C			D			E,F,G			H,I,J,K			L,M,N		
Additional districts 2/		D,E,G			A,B,C,E,G			B,C,D,H,I,K,L			E,F,G,L,M			F,H,I,K		
Number of fuels		40			11			36			17			20		
Test	A.S.T.M.	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Gravity ° A.P.I.	D287	29.0	35.9	44.7	30.3	34.8	36.9	29.5	35.4	39.5	25.8	35.9	41.8	25.8	34.1	41.8
Flash point, Pensky-Martens closed tester ° F.	D93	126	-	206	134	-	172	134	-	218	135	-	210	134	-	230
Viscosity																
Kinematic at 100° F. centistokes	D445	2.05	2.61	3.30	2.05	2.44	2.92	2.05	2.54	3.34	1.77	2.55	3.65	1.60	2.97	4.3
Cloud test ° F.	D97	-15	-	18	-2	-	12	-22	-	15	-40	-	5	-40	-	28
Pour point do.	D97	-20	-	10	-10	-	0	-25	-	0	-40	-	0	<-60	-	20
Sulfur content wt. percent	D129	0.03	0.325	0.80	0.05	0.339	0.60	0.056	0.330	0.96	0.05	0.443	0.99	0.17	0.471	0.87
Aniline point ° F.	D611	118.0	145.4	176.0	118.0	139.1	156	116	140.1	165	87	139.4	160	87	139.4	160
Ramsbottom carbon residue on 10 percent residuum percent	D524	0.003	0.115	0.25	0.03	0.123	0.23	0.03	0.122	0.24	< 0.06	0.098	0.22	<0.06	0.097	0.17
Corrosion, 3 hours at 122° F.	D130	0	-	1	0	-	4	0	-	1	0	-	1	0	-	2
Ash percent	D482	0.000	0.001	0.01	0.0	0.003	0.01	0.000	0.001	0.01	0.000	0.000	0.000	0.00	0.000	<0.01
Water and sediment vol. percent	D96	0.00	0.00	<0.1	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	Trace	0.00	0.00	Trace
Distillation test, on volume recovered basis:	D158															
Initial boiling point ° F.		318	355	460	321	340	370	300	358	460	329	371	405	336	375	440
10 percent		368	425	486	373	415	438	368	424	491	393	432	464	384	439	490
50 percent		461	501	538	480	499	513	468	502	544	439	495	521	410	504	558
90 percent		555	584	630	565	587	618	537	578	618	464	567	624	451	582	648
End point		592	638	668	613	640	675	558	625	675	510	617	676	487	636	708

1/ Regions and districts are shown on map (fig. 1).
2/ Some of the fuels are sold in districts of more than one region.

TABLE 3.--Summary of grade 4 fuels, burner-fuel oil survey, 1955

Geographic distribution of burner fuel oils 1/		Eastern region			Southern region			Central region			Rocky Mountain region			Western region		
Districts within region		A,B,C			D			E,F,G			H,I,J,K			L,M,N		
Additional districts 2/		D,E			B			H,K,L			F,L			F,H,I,K		
Number of fuels		17			3			3			4			3		
Test	A.S.T.M.	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Gravity — ° A.P.I.	D287	12.8	22.1	33.3	14.5	20.8	26.5	14.5	18.7	24.0	14.5	26.0	35.9	14.5	23.2	30.0
Flash point, Pensky-Martens closed tester — ° F.	D93	160	-	230	154	-	225	156	-	240	200	-	240	160	-	240
Viscosity																
Kinematic at 100° F. — centistokes	D445	7.09	17.20	25.0	5.8	13.9	25	14.2	17.9	22.6	6.45	16.1	22.6	10.2	16.4	22.6
Cloud test — ° F.	D97	10	-	34	-	3/ 20	-	-	-	-	-	3/ 10	-	-	3/ 10	-
Pour point — do.	D97	<-45	-	20	-15	-	15	-40	-	0	-40	-	70	-40	-	0
Sulfur content — wt. percent	D129	0.28	0.826	2.05	0.19	0.50	1.0	0.43	1.45	3.27	0.10	1.74	3.27	1.00	2.12	3.27
Aniline point — ° F.	D611	117.2	(4)	178.7	-	3/ 163	-	-	-	-	-	3/ 142	-	-	3/ 142	-
Ramsbottom carbon residue on 100 percent sample — percent	D524	0.45	3.11	6.05	0.10	1.61	4.24	5.0	5.95	7.6	0.06	3.40	7.6	0.06	2.99	7.6
Corrosion, 3 hours at 122° F.	D130	-	-	1	-	-	3/ 5	-	-	-	3/ 0	-	-	3/ 0	-	-
Ash — percent	D482	0.000	0.012	0.042	0.001	0.002	0.005	0.007	0.011	0.018	0.00	0.010	0.03	0.00	0.010	0.02
Water and sediment — vol. percent	D96	0.00	0.15	0.44	-	Trace	-	0.2	0.30	0.7	0.0	0.05	0.1	0.0	0.03	0.10
Distillation test, on volume recovered basis:	D158															
Initial boiling point — ° F.		351	(4)	440	-	3/ 382	-	-	-	-	466	(4)	504	-	3/ 504	-
10 percent		447	-	544	-	500	-	-	-	-	498	-	534	-	534	-
50 percent		534	-	640	-	610	-	-	-	-	570	-	585	-	570	-
90 percent		716	-	748	-	700	-	-	-	-	630	-	744	-	630	-
End point		718	-	842	-	>760	-	-	-	-	686	-	>760	-	686	-

TABLE 4.--Summary of grade 5 fuels, burner-fuel oil survey, 1955

Geographic distribution of burner fuel oils 1/		Eastern region			Southern region			Central region			Rocky Mountain region			Western region		
Districts within region		A,B,C			D			E,F,G			H,I,J,K			L,M,N		
Additional districts 2/		D,E,G			A,B,C,G			C,D,H,I,K,L			E,F,G,L			F,H,I,K		
Number of fuels		13			4			19			9			14		
Test	A.S.T.M.	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Gravity — ° A.P.I.	D287	2.3	15.2	19.5	14.4	16.4	18.0	2.3	13.1	22.0	4.8	11.0	20.2	10.1	14.3	18.5
Flash point, Pensky-Martens closed tester — ° F.	D93	132	-	260	198	-	220	158	-	255	130	-	306	130	-	306
Viscosity																
Kinematic at 100° F. — centistokes	D445	36.4	73.2	116.5	38.38	71.6	130	46.06	76.9	130	47.32	(4)	162	77.7	(4)	162
Furol at 122° F. — seconds	D88	15.6	24.6	40.0	15	24	35	11	24.4	38	18	30.1	40	22.5	32.5	40
Pour point — ° F.	D97	-20	-	40	-15	-	40	-15	-	40	-15	-	60	-20	-	40
Sulfur content — wt. percent	D129	0.43	0.96	2.06	0.73	1.67	2.70	0.50	1.39	3.40	0.810	2.38	4.8	0.5	1.97	4.8
Ramsbottom carbon residue on 100 percent sample — percent	D524	2.69	5.98	10.13	3.8	5.55	8.64	3.8	7.43	11.8	0.61	5.57	10.2	3.80	8.34	14.4
Ash — percent	D482	0.008	0.024	0.053	0.026	0.039	0.05	0.003	0.044	0.19	0.002	0.025	0.09	0.01	0.037	0.07
Water and sediment — vol. percent	D96	0.10	0.33	0.8	0.10	0.30	0.8	0.1	0.25	0.8	Trace	0.13	0.2	Trace	0.13	0.20

TABLE 5.--Summary of grade 6 fuels, burner-fuel oil survey, 1955

Geographic distribution of burner fuel oils 1/		Eastern region			Southern region			Central region			Rocky Mountain region			Western region		
Districts within region		A,B,C			D			E,F,G			H,I,J,K			L,M,N		
Additional districts 2/		D,E,G,J			A,B,C,E,G,J			C,D,H,K,L			A,B,D,E,F,L			F,H,I,K		
Number of fuels		35			14			28			17			24		
Test	A.S.T.M.	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Gravity — ° A.P.I.	D287	3.6	11.8	17.5	6.2	10.6	13.9	-1.1	10.3	23.2	4.5	10.0	20.2	7.8	9.9	15.6
Flash point, Pensky-Martens closed tester — ° F.	D93	154	-	290	152	-	230	160	-	430	150	-	420	150	-	420
Viscosity																
Furol at 122° F. — seconds	D88	64	169.9	290	70	165.3	240	70	195.3	295	51.2	167.7	276.1	70	148.9	236
Pour point — ° F.	D97	10	-	80	10	-	80	20	-	80	20	-	60	5	-	60
Sulfur content — wt. percent	D129	0.56	1.44	3.63	0.45	1.55	2.86	0.60	1.38	3.46	0.40	2.14	5.25	0.5	1.97	5.25
Ramsbottom carbon residue on 100 percent sample — percent	D524	2.78	10.19	22.65	4.5	10.86	22.65	1.30	12.41	20.9	0.61	10.40	21.20	3.75	12.91	18.1
Ash — percent	D482	0.0	0.044	0.15	0.010	0.076	0.15	0.014	0.150	1.9	0.006	0.055	0.4	0.01	0.051	0.11
Water and sediment — vol. percent	D96	0.04	0.29	0.75	0.05	0.283	0.60	0.1	0.32	0.8	Trace	0.42	1.8	0.03	0.20	0.9

1/ Regions and districts are shown on map (fig. 1).
2/ Some of the fuels are sold in districts of more than one region.
3/ Result of test on one sample only.
4/ No average was determined as an insufficient number of samples was represented.

amounts, particularly of the light distillate oil, also are prepared for use as spray oils (insecticides), smudge-pot fuel, adsorption oil, and some as components of jet fuel. Figures indicating recent sales of burner-fuel oil for heating--domestic and industrial, manufacturing processes, steam generation, metallurgy, and similar purposes--are not readily available. The total volumes of distillate and residual fuel oils now comprise virtually 40 percent of the crude oil refined. The importance of these materials has resulted in the need for more information by the petroleum industry, manufacturers of heating appliances, and consumers regarding the types and qualities of such fuels currently being marketed.

Samples of burner-fuel oil typical of their manufacture during the early part of 1955 were analyzed by the refiners in accordance with instructions from the subcommittee on fuel surveys of the Automotive Research Committee of the American Petroleum Institute. Results of the analyses were transmitted to the Bureau of Mines where the data were studied and compiled as shown in the tables of this report.

SUMMARY

Data on a total of 341 samples of burner-fuel oil are represented. The fuels were manufactured by 35 petroleum refining companies, large and small, in 97 refineries throughout the country. The data are divided into 5 groups according to the stated grade of burner-fuel oil, and each group is subdivided into 5 tabulations according to the geographic marketing distribution of the various fuels represented. The geographic areas are 5 general regions of the country containing 14 districts in which the burner-fuel oils are marketed. The areas are shown on the map (fig. 1) and are the same as used in the current diesel-fuel surveys.

Summaries of the results of the tests by grades and by regions are shown in tables 1 through 5. Average values of selected properties are shown for the number of fuels represented, and minimum and maximum figures are given for all the tests indicated, where possible.

EXPLANATION OF TABLES AND FIGURES

Twelve laboratory tests, selected by the subcommittee on fuels surveys of the Automotive Research Committee of the A.P.I. in consultation with the subcommittee on fuel oil characteristics of the Oil-Heat Institute Technical Division and made by procedures approved by the American Society for Testing Materials, 6/ were used to analyze the samples of burner-fuel oils in this survey. By agreement with the cooperating agencies, identification of the items is confidential.

6/ American Society for Testing Materials, ASTM Standards, Part 5, Philadelphia, 1952, 1,350 pp.

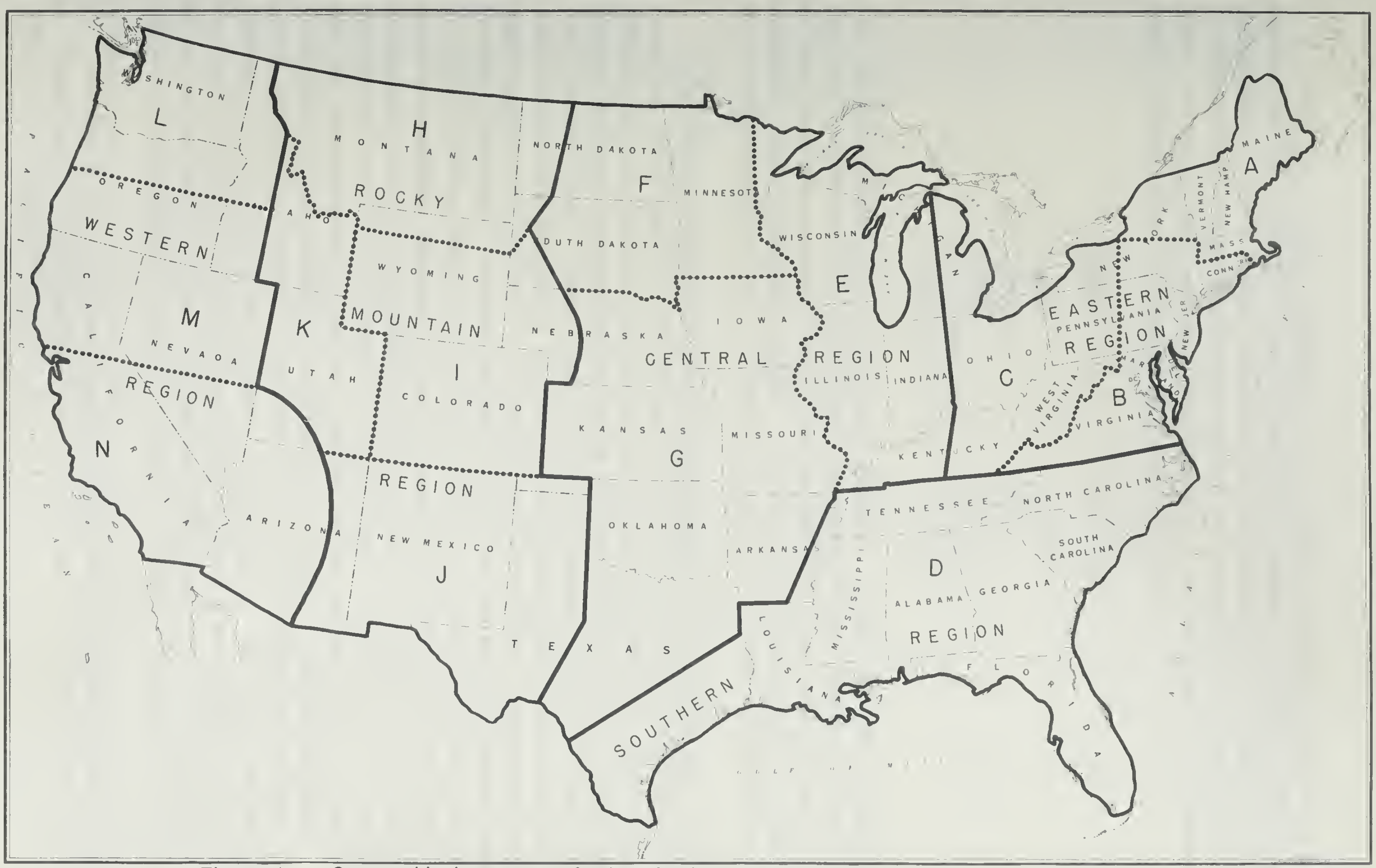

Figure 1. – Geographical areas of the National Survey of Burner-Fuel Oils, 1955.

Each item in tables 6 through 10 is a complete analysis of one sample of burner-fuel oil. The tables are arranged in five groups, according to the grade designations 1, 2, 4, 5, and 6 stated by the manufacturer. Each group of data is subdivided into five tabulations according to the geographic marketing distribution of the fuels represented. The geographic areas are made up of 5 general regions divided into 14 marketing districts as follows:

Region	Districts
Eastern	A, B, C
Southern	D
Central	E, F, G
Rocky Mountain	H, I, J, K
Western	L, M, N

The regions and districts are indicated in figure 1. These areas were established by a study committee of the A.P.I. and are based on fuel-distribution systems, refinery locations, centers of population, temperature zones, and arteries of commerce, such as navigable waters. The districts are the same as now used for the diesel-fuel surveys but are different from those of the motor-gasoline surveys. 7/

The data in tables 6 through 10 are arranged, within each grade group, according to the regions where the fuels are sold. In each regional tabulation the districts where each fuel is sold are given in the second column. The listing of the districts indicates in decreasing order the relative volume of sales for each fuel. Thus, the first district listed is that in which the greatest volume of a fuel is sold, and the analysis of this fuel is tabulated in the first section of data under the region containing that district. The second section of data, separated by a line from the first section, contains analyses of fuels that are sold in greatest volume in districts of other regions. The first section of data in each regional tabulation might be considered to represent fuels of major distribution and the second section to represent fuels of minor distribution for that particular region. It is possible that the sales volume of a given fuel may be highest in a district of one region but that the total sales in districts of another region may be greater. Consider, for example, a fuel distributed in districts C, E, and F. The greatest sales volume might be in district C of the Eastern region, but the combined sales in districts E and F of the Central region could be higher. This fuel would be listed as a fuel of major distribution in the Eastern region and as a fuel of minor distribution in the Central region. It is believed, however, that in most cases the region of greatest sales volume will contain the district of greatest sales volume.

7/ Blade, O. C., National Motor-Gasoline Survey, Winter 1954-55: Bureau of Mines Report of Investigations 5146, 1955, 24 pp. (In cooperation with the American Petroleum Institute).

The first column of these tables shows item numbers of the analyses, each of which represents one sample of burner-fuel oil. The same item number in different tables indicates that this fuel is sold in more than one region, and the analytical data are repeated.

The column headings for the data show the primary ASTM designations of the test procedures. If a test was made by another procedure, the exception is indicated with a footnote. Viscosities of grades 1, 2, 4, and 5 burner-fuel oils were determined in centistokes at 100° F. Viscosities of grades 5 and 6 fuels were determined in Saybolt Furol seconds at 122° F.

Occasionally a certain property of a fuel, other than distillation temperature, is not within the limits of the specification of its grade. 8/ That figure is noted as not included in the average. Most such exceptions are viscosity, sulfur content, and carbon residue. Some of the values were determined to the nearest whole unit and therefore have no decimal. Distillation data are shown by ASTM Method D86 for grade 1 burner-fuel oils and by ASTM D158 for grade 2 fuels, and for grade 4 fuels where given.

Average values of eight or less selected characteristics of all the burner-fuel oils indicated in each of tables 6 through 10 have been computed where possible and are shown at the bottoms of the respective tables. Averages for flash point, cloud test, pour point, and corrosion are not given. Minima and maxima are shown for all the properties.

Summaries of the results of this survey are shown in tables 1, 2, 3, 4, and 5.

8/ American Society for Testing Materials, Tentative Specifications for Fuel Oils (D396-48T): ASTM Standards on Petroleum Products and Lubricants, Philadelphia, 1954, pp. 181-183.

TABLE 6.—Analyses of grade 1 burner fuel oils, 1955

Eastern region: Districts A, B, and C

Item	Distributed in districts 1/	Gravity	Flash point	Viscosity Kinematic at 100° F.	Cloud test	Pour point	Sulfur content	Aniline point	Carbon residue Ramsbottom 2/	Corrosion	Ash	Water and Sediment	Distillation 3/ A.S.T.M. D86 Temperature, °F. % recovered IBP	10	50	90	End point
		A.S.T.M. D287	A.S.T.M. D56	A.S.T.M. D445	A.S.T.M. D97	A.S.T.M. D97	A.S.T.M. D129	A.S.T.M. D611	A.S.T.M. D524 on 10 percent residuum, percent	A.S.T.M. D130 3 hours at 122° F.	A.S.T.M. D482	A.S.T.M. D96					
		° A.P.I.	°F.	cs.	°F.	° F.	percent	°F.			percent	vol. %					
1	A,B,D	43.3	132	1.59	-44	-55	0.04	-	0.13	1A	< 0.001	<0.1	332	372	420	486	518
2	B,A,C	44.0	124	1.50	<-50	<-50	-	147.2	.09	1	-	.0	327	354	407	475	520
3	B,A,D	41.2	134	1.72	<-20	-	.065	-	.07	1	-	-	346	384	440	508	546
4	B,C	42.2	126	1.7	-10	-20	.05	145	.08	1	-	.0	340	375	430	500	540
5	B,D,A	43.1	130	1.7	-30	-40	.05	146	.04	1	-	.0	344	376	422	488	540
6	C	43.2	4/ 134	-	-	<-20	.065	148.6	.00	0	—	.0	342	377	418	470	518
7	C	45.0	4/ 142	1.47	-	<-20	.064	153	.08	0	.003	.0	353	375	418	484	525
8	C	42.6	4/ 135	1.77	-30	-30	.07	-	.08	-	—	.0	341	380	430	491	526
9	C	43.2	4/ 138	-	-	< 0	.09	147	.003	1	.000	.0	349	371	412	474	511
10	C	47.4	142	1.43	-30	-40	.05	156	.02	1	.000	.0	356	380	406	443	496
11	C	46.5	114	1.63	<-20	<-20	.12	168.8	-	1	.00	.0	345	399	428	475	508
12	C	44.8	118	1.45	<-15	<-20	.11	145.8	.06	1A	—	.0	323	350	397	474	538
13	C	45.6	124	5/ 1.27	< 0	< 0	.10	145	.070	1A	.00	.0	332	360	400	458	500
14	C	48.5	132	1.42	-50	-60	.03	159.8	.00	1	.000	.00	332	358	408	463	525
15	C	46.1	140	1.68	-	-	.048	159.6	.06	1	.0	.0	351	377	429	493	542
16	C,E	42.1	126	1.69	<-10	<-10	.13	146.5	.082	1A	.001	.0	336	372	428	514	576
17	C,E	43.4	125	1.57	-56	-60	.219	143.5	.080	1A	-	.0	342	384	428	484	532
18	C,E	44.1	4/ 136	1.7	<-25	<-25	.214	-	.07	1	.000	.0	320	365	424	496	552
19	D,B,A	41.8	133	1.68	< 0	-	.025	-	.01	1	-	-	347	378	422	478	510
20	D,B,A,C	42.2	133	-	-	-	.035	-	-	1	-	.00	337	380	448	524	550
25	E,C	42.6	122	-	<-30	<-30	.272	146.5	-	1A	-	Trace	326	362	428	500	560
26	E,C	41.7	147	-	-	-35	.11	153.8	-	1	-	.0	350	395	450	516	560
27	E,C	40.6	150	2.0	-10	-30	.043	157	.07	1A	.00	.0	346	394	462	540	568
28	E,C,D	42.8	140	1.77	-10	-35	.043	150	.06	1A	.00	.0	366	392	423	468	502
29	E,C,G	42.3	144	-	-	-	.10	-	.08	1	-	-	350	392	434	494	518
Average (25 samples)		43.6	-	1.64	-	-	0.089	151.1	0.059	-	0.000	0.00	341	376	424	488	531
Minimum		40.6	114	1.42	-56	-60	0.025	143.5	0.00	0	0.000	0.00	320	350	397	443	496
Maximum		48.5	150	2.0	0	< 0	.272	168.8	.13	1	.001	< .1	366	399	462	540	576

Southern region: District D

Item	Distributed in districts 1/	Gravity	Flash point	Viscosity	Cloud test	Pour point	Sulfur content	Aniline point	Carbon residue	Corrosion	Ash	Water and Sediment	IBP	10	50	90	End point
19	D,B,A	41.8	133	1.68	< 0	-	0.025	-	0.01	1	-	-	347	378	422	478	510
20	D,B,A,C	42.2	133	-	-	-	.035	-	-	1	-	0.00	337	380	448	524	550
21	D,G,E	42.2	146	1.65	-30	-35	.028	150	.01	0	0.0	.0	351	382	427	488	524
1	A,B,D	43.3	132	1.59	-44	-55	.04	-	.13	1A	< .001	< .1	332	372	420	486	513
3	B,A,D	41.2	134	1.72	<-20	-	.065	-	.07	1	-	-	346	384	440	508	546
5	B,D,A	43.1	130	1.7	-30	-40	.05	146	.04	1	-	.0	344	376	422	488	540
28	E,C,D	42.8	140	1.77	-10	-35	.043	150	.06	1A	.00	.0	366	392	423	468	502
40	G,D,E	44.6	128	1.9	-25	-35	.10	152	.04	1	.00	.0	338	364	416	494	524
Average (8 samples)		42.7	-	1.72	-	-	0.048	150	0.051	-	0.000	0.00	345	379	427	492	527
Minimum		41.2	128	1.59	-44	-55	0.025	146	0.01	0	0.00	0.00	332	364	416	468	502
Maximum		44.6	146	1.9	< 0	-35	.10	152	.13	1	< .001	< .1	366	392	448	524	550

1/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of the fuel. Fuels listed above the lines separating items 18 and 19 in the Eastern region and items 21 and 1 in the Southern region are generally sold in greatest volume in those respective regions. The fuels listed below the lines are generally sold in lesser volumes in the respective regions than in some other regions.

2/ Some of the determinations were made by the Conradson method, A. S. T. M. D189-52, and the data were converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

3/ Distillation figures have been converted, where necessary, to temperatures at 760 mm. Hg according to table 1 in A. S. T. M. D86-52.

4/ Flash point by Pensky-Martin closed tester, A. S. T. M. D93-52. 5/ Not within specification of fuels for this grade, figure not included in average.

Central region: Districts E, F, and G

TABLE 6.—Analyses of grade 1 burner-fuel oils, 1955 (Cont.)

Item	Distributed in districts 1/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D56 °F.	Viscosity Kinematic at 100° F. A.S.T.M. D445 cs.	Cloud test A.S.T.M. D97 °F.	Pour point A.S.T.M. D97 °F.	Sulfur content A.S.T.M. D129 percent	Aniline point A.S.T.M. D611 °F.	Carbon residue Ramsbottom 2/ A.S.T.M. D524 on 10 percent residuum, percent	Corrosion A.S.T.M. D130 3 hours at 122° F.	Ash A.S.T.M. D482 percent	Water and Sediment A.S.T.M. D96 vol. %	Distillation 3/ A.S.T.M. D86 Temperature, °F. % recovered IBP	10	50	90	End point
22	E	42.6	130	1.70	-30	-35	0.08	150	0.09	0	-	Trace	334	365	430	521	565
23	E	42.3	138	1.74	-35	-40	.10	147	.08	1A	0.00	0.0	347	387	438	514	585
24	E	40.1	130	2.10	-	-10	.50	-	.08	1	.000	.00	320	418	464	518	550
25	E,C	42.6	122	-	<-30	<-30	.272	146.5	-	1A	-	Trace	326	362	428	500	560
26	E,C	41.7	147	-	-	-35	.11	153.8	-	1	-	.0	350	395	450	516	560
27	E,C	40.6	150	2.0	-10	-30	.043	157	.07	1A	.00	.0	346	394	462	540	568
28	E,C,D	42.8	140	1.77	-10	-35	.043	150	.06	1A	.00	.0	366	392	423	468	502
29	E,C,G	42.3	144	-	-	-	.10	-	.08	1	-	-	350	392	434	494	518
30	E,G	42.6	130	-	-30	-35	.134	150.8	.06	1A	-	-	348	371	423	501	549
31	E,G	41.9	128	1.71	<-10	<-10	.48	146.1	.060	1	.000	.00	338	370	432	516	566
32	E,G,F	38.8	162	2.0	-20	-30	.430	139	.12	0	.004	.00	387	423	451	495	528
33	E,G,F	42.3	133	1.64	<-50	<-50	4/ .09	147.6	.06	1	.000	.00	346	378	422	470	510
34	E,G,F	40.8	146	2.09	-45	<-50	4/ .11	152.2	.06	1	.000	.00	358	404	458	536	570
35	F,E,G	42.2	136	1.91	-	-30	.18	-	.05	0	.00	.0	344	383	456	522	550
36	F,G,E	44.1	133	-	20	-30	.09	154	-	1	.000	.0	342	365	418	517	567
37	F,H,E	42.9	123	1.6	-	-20	.071	-	.02	1A	-	-	317	360	416	494	548
38	G	41.7	5/ 138	6/ 2.3	-	-40	.12	159	.05	1	-	.0	354	398	450	510	558
39	G	42.3	138	1.76	-36	-45	.05	150	.07	1	.0	.0	344	396	438	484	538
40	G,D,E	44.6	128	1.9	-25	-35	.10	152	.04	1	.00	.0	338	364	416	494	524
41	G,E,F	41.7	143	1.88	-	-25	4/ .100	153.0	.123	1	.000	.0	359	398	452	512	546
42	G,E,F	43.0	130	1.6	-35	-40	.06	140	.07	1	.00	.0	344	374	436	540	565
43	G,E,F	42.2	146	1.86	-26	-35	.04	154.5	.05	1A	—	.0	364	396	442	520	562
44	G,F	42.2	145	1.89	-35	-40	.08	151.8	.068	1	---	.0	368	398	444	510	560
45	G,F,E	43.6	131	1.8	-	<-40	.130	-	.06	1A	---	.00	347	374	425	484	535
46	G,F,E	42.7	128	2.1	-	-25	.072	150.1	.12	1A	—	.0	330	376	434	494	542
47	G,F,E	41.7	148	1.60	-54	-60	.083	-	.095	1	.000	.0	364	387	420	473	514
48	G,F,E	43.8	142	1.90	-24	-30	.10	156	.03	0	-	.0	362	393	456	523	553
49	G,F,E	42.3	140	1.72	-20	-25	.025	154	.07	0	.00	.0	346	391	450	530	560
50	G,F,E,I	42.7	150	1.80	-20	-25	.107	152	.01	0	.00	.0	363	403	449	499	528
16	C,E	42.1	126	1.69	<-10	<-10	.13	146.5	.082	1A	.001	.0	336	372	428	514	576
17	C,E	43.4	125	1.57	-56	-60	.219	143.5	.080	1A	-	.0	342	384	428	484	532
18	C,E	44.1	5/ 136	1.7	<-25	<-25	.214	-	.07	1	.000	.0	320	365	424	496	552
21	D,G,E	42.2	146	1.65	-30	-35	.028	150	.01	0	.0	.0	351	382	427	488	524
58	H,K,L,F	41.2	125	1.54	<-50	<-50	.372	135.9	.105	1	-	.0	332	362	420	502	535
62	I,G	41.4	146	1.6	-44	-55	.05	147	.06	1	.00	.0	360	401	461	540	575
Average (35 samples)		42.3	-	1.79	-	-	0.140	149.6	0.067	-	0.000	0.00	347	385	437	506	548
Minimum		38.8	122	1.54	-56	-60	0.025	135.9	0.01	0	0.000	0.00	317	360	416	468	502
Maximum		44.6	162	2.10	20	-10	.50	159	.123	1	.004	Trace	387	423	464	540	585

Rocky Mountain region: Districts H, I, J, and K

Item	Distributed in districts 1/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D56 °F.	Viscosity Kinematic at 100° F. A.S.T.M. D445 cs.	Cloud test A.S.T.M. D97 °F.	Pour point A.S.T.M. D97 °F.	Sulfur content A.S.T.M. D129 percent	Aniline point A.S.T.M. D611 °F.	Carbon residue Ramsbottom 2/ A.S.T.M. D524 on 10 percent residuum, percent	Corrosion A.S.T.M. D130 3 hours at 122° F.	Ash A.S.T.M. D482 percent	Water and Sediment A.S.T.M. D96 vol. %	Distillation 3/ A.S.T.M. D86 Temperature, °F. % recovered IBP	10	50	90	End point
51	H	41.8	145	1.68	-40	-40	0.377	138	0.002	0	0.00	0.0	375	390	431	491	533
52	H	44.0	134	1.60	-35	-45	.23	142	.05	1	.0	.0	352	371	405	466	520
53	H	43.8	136	1.47	<-30	<-30	7/ .086	-	.06	1	.00	.0	346	370	409	465	496
54	H	41.7	148	1.73	<-30	<-30	7/ .248	-	.08	1	.00	.0	362	391	439	516	567
55	H	43.5	8/ 150	1.6	-	-40	.05	-	.06	-	.00	.0	335	365	405	465	532
56	H,I	41.2	143	1.81	-	-25	.227	143.8	.09	1A	-	.0	382	401	432	485	542
57	H,K,L,I	39.1	150	1.6	-40	-55	6/ .94	136	<.06	0	.00	.0	372	410	446	493	534
58	H,L,K,F	41.2	125	1.54	<-50	<-50	.372	135.9	.105	1	-	.0	332	362	420	502	535
59	I	42.2	150	1.99	-	-30	4/ .032	148.7	.065	1	.001	.00	357	403	443	502	546
60	I	42.1	135	-	<-20	<-20	.018	148.5	.06	1	Trace	Trace	353	395	440	489	527
61	I	42.0	127	1.7	-18	-20	.03	154	.06	1	.00	.0	333	370	456	551	580
62	I,G	41.4	146	1.6	-44	-55	.05	147	.06	1	.00	.0	360	401	461	540	575
63	I,K	44.6	126	1.54	<-25	<-25	.21	146	.034	0	-	.0	347	368	403	493	569
64	J	43.3	138	1.70	-32	-35	.096	146.2	.08	1	.00	.0	353	393	433	489	524
65	J	42.2	120	1.51	-10	<-50	.093	142.6	.06	1	-	.0	336	369	416	482	571
66	K,L	41.8	5/ 140	1.8	-40	-40	.23	152.2	.06	1A	.00	.00	340	393	450	503	574
67	K,L,M	41.9	134	1.80	-20	-40	.11	155	.04	0	.00	.0	325	399	440	486	558
37	F,H,E	42.9	123	1.6	-	-20	.071	-	.02	1A	-	-	317	360	416	494	548
50	G,F,E,I	42.7	150	1.80	-20	-25	.107	152	.01	0	.00	.0	363	403	449	499	528
Average (19 samples)		42.3	-	1.67	-	-	0.147	145.9	0.056	-	0.000	0.00	349	385	431	495	545
Minimum		39.1	120	1.47	<-50	-55	0.018	135.9	0.002	0	0.00	0.00	317	360	403	465	496
Maximum		44.6	150	1.99	-10	-20	.377	155	.105	1	.001	Trace	382	410	461	551	580

Western region: Districts L, M, and N

68	L,M	35.3	5/ 152	2.00	-	< -60	0.20	-	0.07	-	-	Trace	360	407	454	508	570
69	L,M	36.0	5/ 150	2.05	< -30	< -40	.21	130	.08	2	0.00	Trace	360	412	466	533	580
70	L,M,N	42.7	137	1.61	-56	-60	.01	154.3	.03	1	.00	0.0	360	394	435	476	504
71	L,M,N	39.7	156	2.01	-36	-40	.25	143.1	.06	1	.00	.0	396	414	449	503	545
72	L,N	35.2	5/ 162	2.19	< -30	< -40	6/ .72	132	.06	2	.00	.00	368	404	460	549	586
73	L,N	37.7	5/ 140	2.00	-	< -20	.44	-	.11	1	<.01	Trace	336	403	454	514	563
74	N	36.5	185	2.2	-30	-40	.40	140	.09	1	-	.00	365	420	460	525	560
75	N	38.2	5/ 144	2	-38	-40	.1	139	.08	1	.00	.0	330	410	454	510	554
76	N,L,M	37.5	5/ 134	2	<-40	<-40	.3	135	.1	1	.00	.0	323	392	450	526	568
77	N,M	36.3	5/ 134	1.60	<-30	<-40	.17	120	.08	2	.00	.00	348	384	410	451	487
78	N,M,L	38.0	5/ 128	2	-24	-35	.1	140	.1	1	.00	.00	330	384	450	535	570
57	H,K,L,I	39.1	150	1.6	-40	-55	6/ .94	136	<.06	0	.00	.0	372	410	446	493	534
58	H,L,K,F	41.2	125	1.54	<-50	<-50	.372	135.9	.105	1	-	.0	332	362	420	502	535
66	K,L	41.8	5/ 140	1.8	-40	-40	.23	152.2	.06	1A	.00	.00	340	393	450	503	574
67	K,L,M	41.9	134	1.80	-20	-40	.11	155	.04	0	.00	.0	325	399	440	486	558
Average	(15 samples)	38.5	-	1.89	-	-	0.222	139.4	0.075	-	0.000	0.00	350	399	447	508	553
Minimum		35.2	125	1.54	-56	<-60	0.01	120	0.03	0	0.00	0.00	323	362	410	451	487
Maximum		42.7	185	2.2	-20	<-20	.44	155	.11	2	< .01	Trace	396	420	466	549	586

1/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of the fuel. Fuels listed above the lines separating items 50 and 16 in the Central region, items 67 and 37 in the Rocky Mountain region, and items 78 and 57 in the Western region are generally sold in greatest volumes in those respective regions. The fuels listed below the lines are generally sold in lesser volumes in the respective regions than in some other regions.

2/ Some of the determinations were made by the Conradson method, A. S. T. M. D189-52, and the data were converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

3/ Distillation figures have been converted, where necessary, to temperatures at 760 mm. Hg according to table 1 in A. S. T. M. D86-52.

4/ Determined by CO_2-O_2 lamp method, A. S. T. M. D1266-53T modified.

5/ Flash point by Pensky-Martin closed tester, A. S. T. M. D93-52.

6/ Not within specification of fuels for this grade, figure not included in average.

7/ Determined by lamp method, A. S. T. M. D90-50T.

8/ Flash point by Tag open-cup apparatus, A. S. T. M. D1310-54T.

TABLE 7.—Analyses of grade 2 burner-fuel oils, 1955

Eastern region: Districts A, B, and C

Item	Distributed in districts 1/	Gravity A.S.T.M. D287 ° A.P.I	Flash point A.S.T.M. D93 °F.	Viscosity kinematic at 100° F. A.S.T.M. D445 cs.	Cloud test A.S.T.M. D97 °F.	Pour point A.S.T.M. D97 °F.	Sulfur content A.S.T.M. D129 percent	Aniline point A.S.T.M. D611 °F.	Carbon residue Ramsbottom 2/ A.S.T.M. D524 on 10 percent residuum, percent	Corrosion A.S.T.M. D130 3 hours at 122° F.	Ash A.S.T.M. D482 percent	Water and Sediment A.S.T.M. D96 vol. %	Distillation 3/ A.S.T.M. D158 Temperature, °F. IBP	% recovered 10	% recovered 50	% recovered 90	End point
79	B	29.0	180	2.69	10	0	0.80	132	0.20	0	0.000	0.00	359	446	538	610	665
80	B	33.3	148	3.0	0	-10	4/ 1.15	128.5	.05	1	-	.0	340	406	490	580	650
81	B,A	33.2	150	2.51	4	-5	.55	132.8	.25	1	.002	.00	326	408	506	596	652
82	B,A	33.1	168	2.97	-	5	.14	-	.11	1	.0	.0	372	444	512	596	646
83	B,A	32.7	170	2.55	-6	-15	.29	-	.18	1A	<.001	<.1	380	434	490	563	605
84	B,A,C	38.4	166	2.4	-6	-5	.59	152.6	.10	1	.000	.04	368	428	493	582	636
85	B,A,C	35.2	150	2.26	0	-10	.13	138.6	.19	1	-	Trace	336	414	488	570	646
86	B,A,C,D	32.8	158	-	-	-5	.495	-	.16	1	-	.0	338	420	513	596	645
87	B,A,D	34.9	158	2.31	0	-5	.60	-	.23	1	-	-	330	422	496	578	626
88	B,C	35.0	156	2.69	10	0	.60	148	.15	0	.000	.00	345	430	510	600	668
89	B,C	37.5	176	2.71	6	0	.30	156	.13	0	.000	.00	360	440	515	580	665
90	B,C	35.8	140	2.3	10	0	.40	138	.15	1	-	.0	325	410	495	590	630
91	B,D,A	35.7	142	2.3	10	0	.54	131	.10	1	-	.0	322	408	495	578	630
92	B,D,A	34.6	156	2.75	4	-5	.48	143	.10	4	.001	.00	328	426	508	594	644
93	B,D,E	36.6	134	2.05	5	0	.17	143	.16	1	.01	.01	321	373	487	571	638
94	C	33.7	158	2.59	-	0	.29	134.6	.003	-	-	.0	330	432	510	570	622
95	C	39.0	160	2.59	-	0	.28	159	.12	0	.004	.0	365	426	506	604	658
96	C	33.8	150	3.30	8	0	.25	-	4/ .36	-	.0	.05	330	410	492	555	637
97	C	34.7	166	2.8	-	-5	.25	139	.12	-	.000	Trace	367	436	515	594	626
98	C	44.0	168	2.3	-4	-15	.07	166	.03	1	.000	.0	364	409	468	574	609
99	C	41.6	205	3.2	18	10	.07	176	.04	1	.000	.0	444	464	510	630	661
100	C	44.7	126	2.09	-8	-15	.14	174.2	.02	1	.00	.0	318	410	461	556	629
101	C	42.0	158	2.52	8	0	.09	166.1	.04	0	-	.00	366	420	494	584	639
102	C	40.2	160	2.75	12	0	.13	164.3	.06	1	.0	.0	367	435	507	582	622
103	C	36.0	148	2.44	6	0	.25	143.6	.14	1A	-	.0	351	411	502	603	664
104	C	37.2	186	2.93	6	0	.24	160	.062	1A	.00	.0	380	458	516	578	620
105	C	33.4	160	3.30	6	0	.30	126	.089	1A	.00	.0	342	424	501	578	620
106	C	44.2	155	2.54	-8	0	.03	176.0	.01	1	.000	.00	352	403	485	588	658
107	C,E	29.5	206	3.24	7	0	.21	120.0	.180	1A	.001	.0	460	486	530	590	648
108	C,E	38.1	150	3.17	6	0	.284	158.5	.097	1A	-	.0	352	448	532	599	649
109	C,E	33.6	162	2.47	0	-5	.478	153.8	.10	1	.000	.0	368	448	514	572	622

111	D,B,A	33.5	172	2.59	-	-5	.15	-	.06	1	-	-	346	430	511	577	613
112	D,B,A	34.8	158	2.3	10	0	.13	135	.23	1	.0	.0	370	424	480	580	640
113	D,E,C	30.3	162	2.45	0	-10	.5	118.0	.10	0	-	.0	352	438	510	600	640
116	E,C	35.5	141	2.19	-15	-20	.24	127	.10	1A	-	.0	356	429	485	567	621
117	E,C	37.1	5/ 133	2.11	-	-15	.437	139.5	-	1A	-	Trace	342	368	468	568	622
118	E,C	33.7	149	2.7	-	-5	.54	124.0	-	1	-	.0	358	426	503	556	592
119	E,C	36.8	174	2.64	0	-10	.125	154	.08	1B	.00	.0	382	437	492	580	648
120	E,C,G	37.5	152	2.38	12	0	.30	144	.12	0	-	Trace	337	397	505	599	644
121	E,C,G	33.8	174	-	4	0	.8	141	.18	1	-	-	366	420	520	610	664
Average (40 samples)		35.9	-	2.61	-	-	0.325	145.4	0.115	-	0.001	0.00	355	425	501	584	638
Minimum		29.0	126	2.05	-15	-20	0.03	118.0	0.003	0	0.000	0.00	318	368	461	555	592
Maximum		44.7	206	3.30	18	10	.80	176.0	.25	1	.01	< .1	460	486	538	630	668

Southern region: District D

110	D	36.9	168	2.38	-2	0	0.05	146.8	0.08	1	-	0.00	354	427	491	565	627
111	D,B,A	33.5	172	2.59	-	-5	.15	-	.06	1	-	-	346	430	511	577	613
112	D,B,A	34.8	158	2.3	10	0	.13	135	.23	1	0.0	.0	370	424	480	580	640
113	D,E,C	30.3	162	2.45	0	-10	.5	118.0	.10	0	-	.0	352	438	510	600	640
114	D,G,E	36.9	146	2.92	6	0	.056	156	.03	0	.0	.0	344	409	500	599	660
86	B,A,C,D	32.8	158	-	-	-5	.495	-	.16	1	-	.0	338	420	513	596	645
87	B,A,D	34.9	158	2.31	0	-5	.60	-	.23	1	-	-	330	422	496	578	626
91	B,D,A	35.7	142	2.3	10	0	.54	131	.10	1	-	.0	322	408	495	578	630
92	B,D,A	34.6	156	2.75	4	-5	.48	143	.10	4	.001	.00	328	426	508	594	644
93	B,D,E	36.6	134	2.05	5	0	.17	143	.16	1	.01	.01	321	373	487	571	638
132	G,D	36.0	150	2.39	12	0	.56	140.2	.10	1	-	.00	335	386	500	618	675
Average (11 samples)		34.8	-	2.44	-	-	0.339	139.1	0.123	-	0.003	0.00	340	415	499	587	640
Minimum		30.3	134	2.05	-2	-10	0.05	118.0	0.03	0	0.0	0.00	321	373	480	565	613
Maximum		36.9	172	2.92	12	0	.60	156	.23	4	.01	.01	370	438	513	618	675

1/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of the fuel. Fuels listed above the lines separating items 109 and 111 in the Eastern region and items 114 and 86 in the Southern region are generally sold in greatest volume in those respective regions. The fuels listed below the lines are generally sold in lesser volumes in the respective regions than in some other regions.

2/ Some of the determinations were made by the Conradson method, A. S. T. M. D189-52, and the data were converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

3/ Distillation figures have been converted, where necessary, to temperatures at 760 mm. Hg according to table 1 in A. S. T. M. D86-52.

4/ Not within specification of fuels for this grade, figure not included in average.

5/ Flash point by Tag closed tester, A. S. T. M. D56-52.

TABLE 7.—Analyses of grade 2 burner-fuel oils, 1955 (Cont.)

Central region: Districts E, F, and G

Item	Distributed in districts 1/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D93 °F.	Viscosity, Kinematic at 100° F. A.S.T.M. D445 cs.	Cloud test A.S.T.M. D97 °F.	Pour point A.S.T.M. D97 °F.	Sulfur content A.S.T.M. D129 percent	Aniline point A.S.T.M. D611 °F.	Carbon residue Ramsbottom 2/ A.S.T.M. D524 on 10 percent residuum, percent	Corrosion A.S.T.M. D130 3 hours at 122° F.	Ash A.S.T.M. D482 percent	Water and sediment A.S.T.M. D96 vol. %	Distillation 3/ A.S.T.M. D158 Temperature, °F. % recovered IBP	10	50	90	End point
115	E	38.2	145	2.65	4	-10	0.31	153.5	0.16	1	0.000	0.00	300	424	494	610	644
116	E,C	35.5	141	2.19	-15	-20	.24	127	.10	1A	-	.0	356	429	485	567	621
117	E,C	37.1	4/ 133	2.11	-	-15	.437	139.5	-	1A	-	Trace	342	368	468	568	622
118	E,C	33.7	149	2.7	-	-5	.54	124.0	-	1	-	.0	358	426	503	556	592
119	E,C	36.8	174	2.64	0	-10	.125	154	.08	1B	.00	.0	382	437	492	580	648
120	E,C,G	37.5	152	2.38	12	0	.30	144	.12	0	-	Trace	337	397	505	599	644
121	E,C,G	33.8	174	-	4	0	.8	141	.13	1	-	-	366	420	520	610	664
122	E,G	29.6	160	2.5	0	-5	.96	116	.14	1	.00	.0	332	428	544	590	628
123	E,G	38.2	4/ 133	2.38	-	-10	.240	140.5	.09	1A	-	.0	350	394	472	574	620
124	E,G	37.6	158	2.83	15	0	.68	158.0	.070	0	.001	.00	346	418	514	610	670
125	E,G,F	37.8	170	3.3	5	-10	.352	153	.08	0	.005	.0	385	443	501	594	652
126	E,G,F	36.4	166	2.38	-5	-15	5/ .19	143.6	.09	1	.000	.00	368	430	486	556	619
127	F,E,G	33.6	143	2.33	-	-5	.29	-	.15	0	.00	.0	340	393	505	583	620
128	F,G,E	33.3	170	2.57	5	-5	.29	124	.169	1	.000	Trace	373	441	505	578	632
129	F,H,E	35.5	4/ 142	2.38	-	-20	.295	-	.098	1A	-	-	335	399	494	579	633
130	G	34.7	160	2.6	-	-5	.20	129	.16	1	-	.0	354	440	496	576	628
131	G	37.5	218	3.34	-5	-5	.12	165	.09	1	.0	.0	450	491	520	565	620
132	G,D	36.0	150	2.39	12	0	.56	140.2	.10	1	-	.00	335	386	500	618	675
133	G,E,F	34.1	172	2.55	-	-5	5/ .284	130.7	.24	1	.000	.00	366	430	509	564	590
134	G,E,F	37.7	158	2.24	8	-10	.2	142	.17	1	.00	.0	330	399	483	568	631
135	G,E,F	31.9	162	2.43	-4	-5	.22	124.0	.11	1A	-	.0	348	433	508	562	598
136	G,F	33.0	162	2.39	0	-5	.18	121.0	.20	1	-	.0	378	437	500	550	586
137	G,F,E	35.8	4/ 132	2.38	-	-5	.355	-	.06	1A	-	.00	331	426	505	570	613
138	G,F,E	35.9	4/ 141	2.7	-	-5	.254	150.8	.15	1A	-	Trace	338	428	506	572	612
139	G,F,E	36.5	182	2.19	-22	-25	.309	-	.152	1	.001	.0	401	431	483	537	558
140	G,F,E	34.5	160	2.52	2	-5	.21	139	.10	0	-	.0	360	425	515	573	610
141	G,F,E	33.5	160	2.38	2	-5	.12	130	.11	0	.00	.0	350	432	510	578	625
142	G,F,E,I	36.6	160	2.21	-10	-15	.268	145	.08	0	.00	.0	365	430	484	540	587
93	B,D,E	36.6	134	2.05	5	0	.17	143	.15	1	.01	.01	321	373	487	571	638
107	C,E	29.5	206	3.24	7	0	.21	120.0	.180	1A	.001	.0	460	486	530	590	648
108	C,E	38.1	150	3.17	6	0	.284	158.5	.097	1A	-	.0	352	448	532	599	649
109	C,E	33.6	162	2.47	0	-5	.478	153.8	.10	1	.000	.0	368	448	514	572	622
113	D,E,C	30.3	162	2.45	0	-10	.5	118.0	.10	0	-	.0	352	438	510	600	640
114	D,G,E	36.9	146	2.92	5	0	.056	156	.03	0	.0	.0	344	409	500	599	660
146	H,L,K,F	36.5	160	2.52	-18	-20	.78	144.7	.130	1	-	.0	358	414	508	579	606
149	I,G	39.5	156	2.3	-10	-15	.07	155	.08	1	.00	.0	359	430	485	555	599
Average (36 samples)		35.4	-	2.54	-	-	0.330	140.1	0.122	-	0.001	0.00	358	424	502	578	625
Minimum		29.5	134	2.05	-22	-25	0.056	116	0.03	0	0.000	0.00	300	368	468	537	558
Maximum		39.5	218	3.34	15	0	.96	165	.24	1	.01	.01	460	491	544	618	675

Rocky Mountain region: Districts H, I, J, and K

Item	Distributed in districts 1/	Gravity	Flash point	Viscosity	Cloud test	Pour point	Sulfur content	Aniline point	Carbon residue	Corrosion	Ash	Water and sediment	IBP	10	50	90	End point
143	H	35.5	4/ 160	2.8	-	0	0.60	-	0.06	1	0.00	0.0	390	460	515	590	650
144	H,I	35.7	4/ 176	2.38	-	-20	.490	132.9	.12	1A	-	.0	405	430	473	567	620
145	H,K,L,I	34.4	168	2.6	-5	-15	6/ 1.3	138	<.06	0	.00	.0	382	433	519	624	676
146	H,L,K,F	36.5	160	2.52	-18	-20	.78	144.7	.130	1	-	.0	358	414	508	579	606
147	I	35.5	176	1.77	-	-40	5/ .131	108.3	.174	1	.000	.00	394	422	439	464	510

148	I	40.5	135	2.1	-5	-10	.05	158	.06	1	.00	.0	329	403	505	570	600
149	I,G	39.5	156	2.3	-10	-15	.07	155	.08	1	.00	.0	359	430	485	555	599
150	I,K	37.8	164	2.79	0	-10	.64	154	.088	0	-	.0	380	432	503	586	626
151	I,K	35.7	166	2.81	5	-5	.74	148	.11	0	-	.0	384	431	504	582	620
152	J	36.9	185	-	15	-10	.36	152.3	.06	1	.000	.0	387	440	511	604	661
153	K	28.8	186	2.70	-2	-10	.72	106.7	.22	1A	.00	Trace	397	464	515	563	622
154	K,L	41.8	140	1.8	-40	-40	.23	152.2	.06	1A	.00	.00	340	393	450	503	574
155	K,L	37.3	158	2.60	2	-10	.37	149.0	.09	1A	.00	.00	357	435	494	574	645
156	K,L,M	36.9	168	3.37	2	-5	.35	160	.07	0	.00	.0	363	458	521	580	629
157	K,L,M	25.8	210	3.65	-30	-35	.99	87	.10	0	.00	.0	380	463	503	572	635
129	F,H,E	35.5	4/ 142	2.38	-	-20	.295	-	.098	1A	-	-	335	399	494	579	633
142	G,F,E,I	36.6	160	2.21	-10	-15	.268	145	.08	0	.00	.0	365	430	484	540	587
Average (17 samples)		35.9	-	2.55	-	-	0.443	139.4	0.098	-	0.000	0.00	371	432	495	567	617
Minimum		25.8	135	1.77	-40	-40	0.05	87	<0.06	0	0.000	0.00	329	393	439	464	510
Maximum		41.8	210	3.65	5	0	.99	160	.22	1	.000	Trace	405	464	521	624	676

Western region: Districts L, M, and N

158	L,M	35.3	152	2.00	-	<-60	0.20	-	0.07	-	-	Trace	360	407	454	508	570
159	L,M	31.7	186	3.80	20	0	-	-	-	-	-	do	402	464	546	648	704
160	L,M	36.0	150	2.05	<-30	<-40	.21	130	.08	2	0.00	do	360	412	466	533	580
161	L,M	30.6	174	3.60	10	0	.52	136	.06	2	.00	do	378	455	540	618	670
162	L,N	35.2	162	2.19	<-30	<-40	.72	132	.06	2	.00	0.00	368	404	460	549	586
163	L,N	30.7	200	3.95	15	5	6/ 1.04	140	.06	2	.00	.00	410	470	538	634	698
164	L,N	37.7	140	2.00	-	<-20	.44	-	.11	1	<.01	Trace	336	403	454	514	563
165	N	34.2	174	3.5	22	20	.2	152	.16	1	.00	.0	378	454	536	642	708
166	N	32.0	230	4.3	10	0	.65	155	.10	1	-	.00	440	490	550	625	675
167	N,L	33.0	180	3.2	12	5	.87	-	.17	1	<.01	Trace	372	451	535	627	695
168	N,L,M	31.8	176	3.4	5	0	.7	140	.17	1	.00	.0	370	466	536	607	649
169	N,M	36.3	134	1.60	<-30	<-40	.17	120	.08	2	.00	.00	348	384	410	451	487
170	N,M	33.2	160	3.00	10	0	.31	145	.06	2	.00	.00	374	438	507	621	686
171	N,M,L	31.1	206	4.3	28	20	.3	149	.15	1	.00	.00	428	488	558	627	674
145	H,K,L,I	34.4	168	2.6	-5	-15	6/ 1.3	138	< .06	0	.00	.0	382	433	519	624	676
146	H,L,K,F	36.5	160	2.52	-18	-20	.78	144.7	.130	1	-	.0	358	414	508	579	606
154	K,L	41.8	140	1.8	-40	-40	.23	152.2	.06	1A	.00	.00	340	393	450	503	574
155	K,L	37.3	158	2.60	2	-10	.37	149.0	.09	1A	.00	.00	357	435	494	574	645
156	K,L,M	36.9	168	3.37	2	5	.35	160	.07	0	.00	.0	363	458	521	580	629
157	K,L,M	25.8	210	3.65	-30	-35	.99	87	.10	0	.00	.0	380	463	503	572	635
Average (20 samples)		34.1	-	2.97	-	-	0.471	139.4	0.097	-	0.000	0.00	375	439	504	582	636
Minimum		25.8	134	1.60	-40	<-60	0.17	87	<0.06	0	0.00	0.00	336	384	410	451	487
Maximum		41.8	230	4.3	28	20	.87	160	.17	2	<.01	Trace	440	490	558	648	708

1/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of the fuel. Fuels listed above the lines separating items 142 and 93 in the Central region, items 157 and 129 in the Rocky Mountain region, and items 171 and 145 in the Western region are generally sold in greatest volume in those respective regions. The fuels listed below the lines are generally sold in lesser volumes in the respective regions than in some other regions.

2/ Some of the determinations were made by the Conradson method, A. S. T. M. D189-52, and the data were converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

3/ Distillation figures have been converted, where necessary, to temperatures at 760 mm. Hg according to table 1 in A. S. T. M. D86-52.

4/ Flash point by Tag closed tester, A. S. T. M. D56-52.

5/ Determined by CO_2-O_2 lamp method, A. S. T. M. D1266-53T.

6/ Not within specification of fuels for this grade, figure not included in average.

TABLE 8.--Analyses of grade 4 burner-fuel oils, 1955

Eastern region: Districts A, B, and C

Item	Distributed in districts 1/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D93 °F.	Viscosity, kinematic at 100° F. A.S.T.M. D445 cs.	Cloud test A.S.T.M. D97 °F.	Pour point A.S.T.M. D97 °F.	Sulfur content A.S.T.M. D129 percent	Aniline point A.S.T.M. D611 °F.	Carbon residue Ramsbottom 2/ A.S.T.M. D524 on 100 percent sample, percent	Corrosion A.S.T.M. D130 3 hours at 122° F.	Ash A.S.T.M. D482 percent	Water and Sediment A.S.T.M. D96 vol. %	Distillation 3/ A.S.T.M. D158 Temperature, °F. IBP	% recovered 10	50	90	End point
172	A,B	14.1	225	15.2	-	-30	0.81	-	3.50	-	0.006	0.2	424	-	-	-	-
173	A,B	12.8	210	18.9	-	<-45	.95	-	4.66	1	.00	.3	416	514	640	(4)	-
174	B	13.9	>200	16.8	-	-45	.81	-	-	-	.005	.44	440	520	636	(5)	-
175	B	22.3	170	21.0	10	< 0	2.05	-	5.49	-	.03	.10	-	-	-	-	-
176	B	22.6	196	6/ 5.29	-	-15	.53	117.2	7/ .45	1	.004	.00	8/370	458	534	720	842
177	B	17.9	200	25.0	-	-10	2.0	-	6.05	-	.025	.15	-	-	-	-	-
178	B	22.4	176	18.4	-	-15	.60	-	3.4	-	.02	.1	-	-	-	-	-
179	B,A,C	22.0	184	23.5	-	5	.28	-	2.27	-	.02	.2	-	-	-	-	-
180	B,C	23.1	> 200	19	-	10	1.60	-	2.10	-	.02	.2	-	-	-	-	-
181	C	22.0	212	19.10	-	0	.52	-	4.02	-	-	.2	-	-	-	-	-
182	C	31.1	230	9.2	-	0	.42	-	1.36	-	.000	.1	-	-	-	-	-
183	C	33.0	205	8.86	34	20	.30	178.7	9/ -	1	.0	.0	415	544	632	748	>760
184	C	33.3	160	7.09	24	0	.33	172.9	10/ -	1	.0	.0	351	447	626	716	718
185	C	22.7	182	20.57	-	10	.58	-	4.83	-	.008	.2	-	-	-	-	-
186	C	16.2	160	22.9	-	-25	.444	-	2.03	-	.011	.1	-	-	-	-	-
187	C,B	24.2	180	18.72	-	10	.820	-	2.83	-	.042	.2	-	-	-	-	-
190	D,B	21.5	154	11.0	-	0	1.0	-	.48	-	.001	Trace	-	-	-	-	-
Average (17 samples)		22.1	-	17.20	-	-	0.826	-	3.11	-	0.012	0.15	-	-	-	-	-
Minimum		12.8	160	7.09	10	<-45	0.28	117.2	0.45	-	0.000	0.00	351	447	534	716	718
Maximum		33.3	230	25.0	34	20	2.05	178.7	6.05	1	.042	.44	440	544	640	748	842

Southern region: District D

Item	Distributed in districts	Gravity	Flash point	Viscosity	Cloud test	Pour point	Sulfur content	Aniline point	Carbon residue	Corrosion	Ash	Water and Sediment	IBP	10	50	90	End point
188	D	26.5	188	5.8	20	15	0.30	163	10/ 0.10	5	0.001	Trace	382	500	610	700	>760
189	D	14.5	225	25	-	-15	.19	-	4.24	-	.005	do	-	-	-	-	-
190	D,B	21.5	154	11.0	-	0	1.0	-	.48	-	.001	do	-	-	-	-	-
Average (3 samples)		20.8	-	13.9	-	-	0.50	-	1.61	-	0.002	Trace	-	-	-	-	-
Minimum		14.5	154	5.8	-	-15	0.19	-	0.10	-	0.001	-	-	-	-	-	-
Maximum		26.5	225	25	-	15	1.0	-	4.24	5	.005	-	-	-	-	-	-

Central region: Districts E, F, and G

191	E	24.0	167	17	-	-25	0.43	-	5.0	-	0.007	0.2	-	-	-	-	-
192	E	17.7	156	14.2	-	0	.66	-	5.25	-	.018	.7	-	-	-	-	-
194	H,L,K,F	14.5	240	22.6	-	-40	3.27	-	7.6	-	.009	Trace	-	-	-	-	-
Average (3 samples)		18.7	-	17.9	-	-	1.45	-	5.95	-	0.011	0.30	-	-	-	-	-
Minimum		14.5	156	14.2	-	-40	0.43	-	5.0	-	0.007	0.2	-	-	-	-	-
Maximum		24.0	240	22.6	-	0	3.27	-	7.6	-	.018	.7	-	-	-	-	-

Rocky Mountain region: Districts H, I, J, and K

193	H,K,L,I	30.0	200	6/ 4.2	10	0	2.1	142	0.06	0	0.00	0.0	504	534	570	630	686
194	H,L,K,F	14.5	240	22.6	-	-40	3.27	-	7.6	-	.009	Trace	-	-	-	-	-
195	I,J,K	35.9	240	6.45	-	70	.10	-	-	-	.03	.1	466	493	585	744	>760
196	J	23.6	200	19.1	-	-20	1.49	-	2.55	-	Trace	.1	-	-	-	-	-
Average (4 samples)		26.0	-	16.1	-	-	1.74	-	3.40	-	0.010	0.05	-	-	-	-	-
Minimum		14.5	200	6.45	-	-40	0.10	-	0.06	-	0.00	0.0	466	493	570	630	686
Maximum		35.9	240	22.6	-	70	3.27	-	7.6	-	.03	.1	504	534	585	744	>760

Western region: Districts L, M, and N

197	N	25.0	160	10.2	-	-10	1.00	-	1.30	-	0.02	0.10	-	-	-	-	-
193	H,K,L,I	30.0	200	6/ 4.2	10	0	2.1	142	.06	0	.00	.0	504	534	570	630	686
194	H,L,K,F	14.5	240	22.6	-	-40	3.27	-	7.6	-	.009	Trace	-	-	-	-	-
Average (3 samples)		23.2	-	16.4	-	-	2.12	-	2.99	-	0.010	0.03	-	-	-	-	-
Minimum		14.5	160	10.2	-	-40	1.00	-	0.06	-	0.00	0.0	-	-	-	-	-
Maximum		30.0	240	22.6	-	0	3.27	-	7.6	-	.02	.10	-	-	-	-	-

1/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of the fuel. Fuels listed above the lines separating items 187 and 190 in the Eastern region, items 192 and 194 in the Central region and items 197 and 193 in the Western region are generally sold in greatest volume in those respective regions. The fuels listed below the lines are generally sold in lesser volumes in the respective regions than in some other regions.

2/ Some of the determinations were made by the Conradson method, A. S. T. M. D189-52, and the data were converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

3/ Distillation figures have been converted, where necessary, to temperatures at 760 mm. Hg according to table 1 in A. S. T. M. D86-52.

4/ 688° F. at 86.5 percent recovered. 5/ Cracking. 6/ Not within specification of fuels for this grade, figure not included in average.

7/ Ramsbottom carbon residue on 10% residuum, 1.80 percent.

8/ Equivalent distillation temperatures at 760 mm. Hg converted from figures at 10 mm. pressure according to chart (fig. 5) in the report by Beale, E.S.L., and Docksey, P., A Wide Range Boiling-Point Conversion Chart for Hydrocarbons and Petroleum Products; Jour. Inst. Petrol. Technol., vol. 21, 1935, pp. 860-870.

9/ Ramsbottom carbon residue on 10% residuum, 0.26 percent. 10/ Ramsbottom carbon residue on 10% residuum, 0.24 percent.

TABLE 9.—Analyses of grade 5 burner-fuel oils, 1955

Item	Distributed in districts 1/	Gravity	Flash point	Viscosity: Kinematic at 100° F.	Viscosity: Furol at 122° F.	Pour point	Sulfur content	Carbon residue Ramsbottom 2/	Ash	Water and sediment
		A.S.T.M. D287	A.S.T.M. D93	A.S.T.M. D445	A.S.T.M. D88	A.S.T.M. D97	A.S.T.M. D129	A.S.T.M. D524	A.S.T.M. D482	A.S.T.M. D96
		° A.P.I.	°F.	cs.	Sec.	°F.	percent	on 100 percent sample, percent	percent	vol.%
Eastern region: Districts A, B, and C										
198	B	16.9	205	73.4	22.0	10	2.06	7.02	0.030	0.15
199	B	18.8	178	40	17	-20	1.0	6.3	.03	.1
200	B,A,C,D	17.0	>200	42	-	15	-	-	.04	.8
201	C	18.3	220	-	34.3	5	.68	2.85	-	.4
202	C	8.2	132	89.0	24	0	1.70	7.45	.012	.8
203	C	18.8	208	73.8	26	0	.63	5.98	-	.2
204	C	13.8	184	61.2	20	0	.64	6.78	.008	.2
205	C	19.5	205	-	40.0	30	.70	6.28	.010	.6
206	C	19.5	260	36.4	15.6	0	.43	5.29	.016	.10
207	C	11.8	175	108.6	26.5	15	.611	2.69	.015	.15
208	C,E	18.4	230	116.5	-	40	1.24	5.05	.053	.3
217	E,C,G	13.7	170	-	-	0	-	-	-	-
224	G,E,C	2.3	>150	91.2	21	15	.87	10.13	.028	.2
Average	(13 samples)	15.2	-	73.2	24.6	-	0.96	5.98	0.024	0.33
Minimum		2.3	132	36.4	15.6	-20	0.43	2.69	0.008	0.10
Maximum		19.5	260	116.5	40.0	40	2.06	10.13	.053	.8
Southern region: District D										
209	D	18.0	198	38.38	15	-15	0.73	8.64	0.04	0.10
210	D	16.1	210	76.0	23.0	-15	1.58	4.22	.026	.10
200	B,A,C,D	17.0	>200	42	-	15	-	-	.04	.8
221	G,D	14.4	220	130	35	40	2.70	3.8	.05	.2
Average	(4 samples)	16.4	-	71.6	24	-	1.67	5.55	0.039	0.30
Minimum		14.4	198	38.38	15	-15	0.73	3.8	0.026	0.10
Maximum		18.0	220	130	35	40	2.70	8.64	.05	.8
Central region: Districts E, F, and G										
211	E	19.5	168	110	25.4	0	0.50	6.0	0.009	0.2
212	E	16.5	170	3/ 19.57	-	-15	1.26	-	.03	.3
213	E	13.1	190	-	38	20	1.60	-	.19	.3
214	E	18.2	162	54.0	19	0	.90	7.70	.040	.8
215	E	14.1	158	-	20	<-10	3.28	9.94	.014	.20
216	E	22.0	255	64.7	-	0	1.50	4.6	.04	.25
217	E,C,G	13.7	170	-	-	0	-	-	-	-
218	G	7.0	215	58.0	-	0	.8	8.4	.02	.1
219	G	13.8	165	3/ 14.16	11	-10	.67	5.2	.04	.2
220	G	16.0	245	-	32	15	.92	11.8	.05	.2
221	G,D	14.4	220	130	35	40	2.70	3.8	.05	.2
222	G,E	11.7	240	46.06	-	-5	.910	-	.03	.2
223	G,E	17.0	242	-	22.7	20	.882	6.3	.03	.20
224	G,E,C	2.3	>150	91.2	21	15	.87	10.13	.028	.2
225	G,E,F	9.2	190	-	22	-10	1.42	-	.054	.3

226	G,E,I	4.8	245	49.98	-	-15	.810	-	.003	.2
227	G,F,E,I	6.0	240	47.32	-	-5	1.31	-	.09	.15
208	C,E	18.4	230	116.5	-	40	1.24	5.05	.053	.3
231	H,L,K,F	10.9	245	77.7	22.5	-10	3.40	10.2	.016	.2
Average	(19 samples)	13.1	-	76.9	24.4	-	1.39	7.43	0.044	0.25
Minimum		2.3	158	46.06	11	-15	0.50	3.8	0.003	0.1
Maximum		22.0	255	130	38	·40	3.40	11.8	.19	.8

Rocky Mountain region: Districts H, I, J, and K

228	H	7.4	162	-	36.0	30	3.15	8.2	0.01	0.1
229	H,K,L,I	17.5	306	162	38	40	4.8	4.4	.01	Trace
230	H,L	10.1	130	-	40	15	2.46	8.7	.03	-
231	H,L,K,F	10.9	245	77.7	22.5	-10	3.40	10.2	.016	.2
232	I	6.2	206	-	18	10	2.90	5.8	.002	.1
233	K	20.2	300	-	35.5	60	1.20	.61	.01	.10
234	K	15.6	170	-	21.0	40	1.39	1.05	.05	.2
226	G,E,I	4.8	245	49.98	-	-15	.810	-	.003	.2
227	G,F,E,I	6.0	240	47.32	-	-5	1.31	-	.09	.15
Average	(9 samples)	11.0	-	-	30.1	-	2.38	5.57	0.025	0.13
Minimum		4.8	130	47.32	18	-15	0.810	0.61	0.002	Trace
Maximum		20.2	306	162	40	60	4.8	10.2	.09	0.2

Western region: Districts L, M, and N

235	L,M	12.3	204		28.3	-15	0.96	7.41	0.05	0.2
236	L,M	13.9	200	-	33.0	-15	.90	9.1	.03	.20
237	L,M,N	15.6	214	-	30	5	1.10	14.4	.03	.2
238	L,N	11.8	176	-	34.0	-15	1.73	11.0	.05	.10
239	N	15.2	155	-	35	15	2.9	-	.07	.2
240	N	18.5	200	-	34	20	.5	3.80	.01	.1
241	N	13.5	170	-	30	0	1.30	12.0	.06	.20
242	N,L	15.2	198	-	27	5	1.69	8.52	.04	.1
243	N,L,M	12.9	184	-	32	5	1.4	8.0	.05	.1
244	N,M	17.4	194	-	39.0	-20	.94	3.88	.02	.10
245	N,M,L	14.7	174	-	32	10	3.5	7.0	.05	.02
229	H,K,L,I	17.5	306	162	38	40	4.8	4.4	.01	Trace
230	H,L	10.1	130	-	40	15	2.46	8.7	.03	-
231	H,L,K,F	10.9	245	77.7	22.5	-10	3.40	10.2	.016	.2
Average	(14 samples)	14.3	-	-	32.5	-	1.97	8.34	0.037	0.13
Minimum		10.1	130	77.7	22.5	-20	0.5	3.80	0.01	Trace
Maximum		18.5	306	162	40	40	4.8	14.4	.07	0.20

1/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of the fuel. Fuels listed above the lines separating items 208 and 217 in the Eastern region, items 210 and 200 in the Southern region, items 227 and 208 in the Central region, items 234 and 226 in the Rocky Mountain region, and items 245 and 229 in the Western region are generally sold in greatest volume in those respective regions. The fuels listed below the lines are generally sold in lesser volumes in the respective regions than in some other region.

2/ Some of the determinations were made by the Conradson method, A. S. T. M. D189-52, and the data converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

3/ Not within specification of fuels for this grade, figure not included in average.

TABLE 10.--Analyses of grade 6 burner fuel oils, 1955

Eastern region: Districts A, B, and C

Item	Distributed in districts 1/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D93 °F.	Viscosity Furol at 122° F. A.S.T.M. D88 Sec.	Pour point A.S.T.M. D97 °F.	Sulfur content A.S.T.M. D129 percent	Carbon residue Ramsbottom 2/ A.S.T.M. D524 on 100 percent sample, percent	Ash A.S.T.M. D482 percent	Water and Sediment A.S.T.M. D96 vol.%
246	A,D	6.2	182	206	40	1.24	14.71	0.010	0.4
247	B	11.5	185	180	35	2.45	9.25	.030	.15
248	B	15.9	192	160	40	3/ 1.0	13.4	.04	.3
249	B	14.3	190	160	30	4/ 2.4	15.1	.04	.2
250	B	10.8	188	168	40	2.40	13.8	.05	.3
251	B	14.6	250	151	35	4/ 2.90	8.44	.04	.2
252	B	15.1	154	192	20	3.63	10.89	.05	.4
253	B	15.4	200	78	60	1.9	6.2	.1	.5
254	B,A	10.3	196	170	35	1.81	16.28	.11	.18
255	B,A	8.4	200	221	25	3.25	13.8	.072	.2
256	B,A,D	10.6	190	150.6	25	1.80	-	.04	.05
257	B,A,D	11.3	200	142	-	.60	-	.06	.20
258	B,A,D,C	10.0	>200	173	35	2.32	-	.15	.60
259	B,C	16.7	210	142	75	3/ .77	6.17	.05	.2
260	B,D	7.5	164	163	30	1.42	22.65	.07	.20
261	C	16.0	225	95.2	10	.79	4.06	-	.4
262	C	4.2	210	120	30	1.80	11.1	.012	.6
263	C	7.1	220	150	30	.91	9.0	.010	.4
264	C	17.5	170	69	45	.72	3.85	-	.2
265	C	12.5	212	64	25	.84	10.0	.006	.2
266	C	13.1	190	69	15	.56	6.27	.01	.04
267	C	12.2	195	200	35	.62	6.85	.025	.2
268	C	16.8	240	98.9	25	.77	7.5	.0	.75
269	C	16.5	180	213.5	75	.85	8.42	.036	.5
270	C	14.3	240	290	80	.75	9.4	.012	.6
271	C	14.5	290	275.0	40	.68	7.60	.017	.20
272	C	8.5	260	280	25	.774	2.78	.026	.2
273	C,E	16.0	245	162	50	1.32	6.72	.064	.3
277	D,B	10.8	198	175	20	2.77	-	.10	.12
278	D,B,A	13.0	208	70	10	1.95	9.44	.010	.4
279	D,B,A	9.0	170	240	45	.75	9.0	.03	.2
280	D,B,A,J	7.2	190	185	25	1.5	13.5	.02	.1
288	E,C	14.3	228	236	45	.60	9.0	.014	.3
289	E,C	8.0	180	228	40	.62	16.1	.09	.2
298	G,E,C	3.6	>150	270	35	.87	14.50	.044	.3
Average (35 samples)		11.8	-	169.9	-	1.44	10.19	0.044	0.29
Minimum		3.6	154	64	10	0.56	2.78	0.0	0.04
Maximum		17.5	290	290	80	3.63	22.65	.15	.75

Southern region: District D

Item	Distributed in districts 1/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D93 °F.	Viscosity Furol at 122° F. A.S.T.M. D88 Sec.	Pour point A.S.T.M. D97 °F.	Sulfur content A.S.T.M. D129 percent	Carbon residue Ramsbottom 2/ A.S.T.M. D524 on 100 percent sample, percent	Ash A.S.T.M. D482 percent	Water and Sediment A.S.T.M. D96 vol.%
274	D	10.1	200	150	35	1.77	11.75	0.09	0.10
275	D	13.0	152	170	35	.45	4.5	.3	.5
276	D	13.9	205	198	30	1.50	10.51	.052	.190
277	D,B	10.8	198	175	20	2.77	-	.10	.12
278	D,B,A	13.0	208	70	10	1.95	9.44	.010	.4
279	D,B,A	9.0	170	240	45	.75	9.0	.03	.2
280	D,B,A,J.	7.2	190	185	25	1.5	13.5	.02	.1
281	D,E,G	13.9	5/ 355	122.2	80	.719	7.8	.047	.60
246	A,D	6.2	182	206	40	1.24	14.71	.010	.4
256	B,A,D	10.6	190	150.6	25	1.80	-	.04	.05
257	B,A,D	11.3	200	142	-	.60	-	.06	.20
258	B,A,D,C	10.0	>200	173	35	2.32	-	.15	.60
260	B,D	7.5	164	163	30	1.42	22.65	.07	.20
299	G,E,D	12.0	230	170	50	2.86	4.7	.08	.3
Average (14 samples)		10.6	-	165.3	-	1.55	10.86	0.076	0.283
Minimum		6.2	152	70	10	0.45	4.5	0.010	0.05
Maximum		13.9	230	240	80	2.86	22.65	.15	.60

1/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of the fuel. Fuels listed above the lines separating items 273 and 277 in the Eastern region and items 281 and 246 in the Southern region, are generally sold in greatest volume in those respective regions. The fuels listed below the lines are generally sold in lesser volumes in the respective regions than in some other region.

2/ Some of the determinations were made by the Conradson method, A. S. T. M. D189-52, and the data converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

3/ Designated low-sulfur fuel. 4/ Designated high-sulfur fuel. 5/ Flash point by Cleveland open cup method, A. S. T. M. D92-52.

TABLE 10. --Analyses of grade 6 burner fuel oils, 1955 (Cont.)

Central region: Districts E, F, and G

Item	Distributed in districts 1/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D93 °F.	Viscosity, Furol at 122° F. A.S.T.M. D88 sec.	Pour point A.S.T.M. D97 °F.	Sulfur content A.S.T.M. D129 percent	Carbon residue Ramsbottom 2/ A.S.T.M. D524 on 10 percent residuum, percent	Ash A.S.T.M. D482 percent	Water and Sediment A.S.T.M. D96 vol. %
282	E	15.8	190	85	40	2.70	-	0.03	0.2
283	E	11.5	166	175	45	3/ .98	10.80	.045	.8
284	E	13.8	172	250	45	4/1.30	12.40	.048	.8
285	E	8.4	160	204	40	3.42	13.76	.052	.30
286	E	23.2	430	91.1	75	.70	4.16	.034	.50
287	E	6.3	255	128.2	30	1.11	1.30	.03	.20
288	E,C	14.3	228	236	45	.60	9.0	.014	.3
289	E,C	8.0	180	228	40	.62	16.1	.09	.2
290	E,F,G	11.5	>230	70	-	.90	7.5	.11	.3
291	G	14.6	200	290	-	.90	18.0	1.9	.2
292	G	7.8	165	215	30	.9	14.5	.1	.3
293	G	2.0	270	6/ 44	20	.9	10.5	.03	.1
294	G	13.5	250	145	30	1.13	13.2	.1	.2
295	G	13.1	275	275	35	1.39	15.0	.1	.2
296	G,E	16.8	325	131	30	1.00	-	-	.1
297	G,E	14.2	175	290	30	1.20	20.8	.03	.5
298	G,E,C	3.6	>150	270	35	.87	14.50	.044	.3
299	G,E,D	12.0	230	170	50	2.86	4.7	.08	.3
300	G,E,F	13.8	210	295	40	.9	13.65	.355	.5
301	G,E,F	11.2	5/ 360	278	50	.982	13.08	.065	.2
302	G,E,F	-1.1	310	131	40	1.33	-	.04	.3
303	G,F,E	2.2	325	124	45	.949	-	-	.2
304	G,F,E	.0	208	289	45	1.36	20.9	.02	.1
305	G,F,E	8.1	215	265	45	.73	17.7	.05	.3
273	C,E	16.0	245	162	50	1.32	6.72	.064	.3
281	D,E,G	13.9	5/ 355	122.2	80	.719	7.8	.047	.60
307	H,F,E	6.0	180	265	40	3.4	17.5	.4	.5
311	H,L,K,F	8.4	250	89.6	20	3.46	14.2	.026	.2
Average (28 samples)		10.3	-	195.3	-	1.38	12.41	0.150	0.32
Minimum		-1.1	160	70	20	0.60	1.30	0.014	0.1
Maximum		23.2	430	295	80	3.46	20.9	1.9	.8

Rocky Mountain region: Districts H,I,J, and K

Item	Distributed in districts 1/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D93 °F.	Viscosity, Furol at 122° F. A.S.T.M. D88 sec.	Pour point A.S.T.M. D97 °F.	Sulfur content A.S.T.M. D129 percent	Carbon residue Ramsbottom 2/ A.S.T.M. D524 on 10 percent residuum, percent	Ash A.S.T.M. D482 percent	Water and Sediment A.S.T.M. D96 vol. %
306	H	4.5	188	278	35	3.24	15.0	0.01	0.2
307	H,F,E	6.0	180	265	40	3.4	17.5	.4	.5
308	H,K,L,I	14.9	420	115	60	5.25	5.7	.07	Trace
309	H,L	9.0	150	70	25	2.4	13.7	.03	.2
310	H,L,K	7.8	200	146.1	35	2.50	3.75	.015	.9
311	H,L,K,F	8.4	250	89.6	20	3.46	14.2	.026	.2
312	I	10.6	5/ 430	276.1	50	.621	6.74	.031	1.0
313	I	6.7	194	162	55	2.98	7.81	.011	Trace
314	I	10.3	190	290	60	.40	13.0	.11	.5
315	I	10.5	180	150	50	.8	13.0	.04	.3
316	I	6.7	222	170	30	2.96	12.4	.006	.1
317	J	10.2	180	97.5	30	1.31	16.54	.019	1.0
318	J	6.8	197	203	35	1.53	21.20	.032	1.8
319	K	20.2	300	6/ 35.5	60	1.20	.61	.01	.10
320	K	15.8	300	135.0	60	1.40	.89	.02	.10
321	K	15.1	200	51.2	55	1.45	1.33	.08	.2
280	D,B,A,J	7.2	190	185	25	1.5	13.5	.02	.1
Average (17 samples)		10.0	-	167.7	-	2.14	10.40	0.055	0.42
Minimum		4.5	150	51.2	20	0.40	0.61	0.006	Trace
Maximum		20.2	420	276.1	60	5.25	21.20	.4	1.8

1/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of the fuel. Fuels listed above the lines separating items 305 and 273 in the Central region, and items 321 and 280 in the Rocky Mountain region are generally sold in greatest volume in those respective regions. The fuels listed below the lines are generally sold in lesser volumes in the respective regions than in some other region.

2/ Some of the determinations were made by the Conradson method, A. S. T. M. D189-52, and the data converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

3/ Designated low-sulfur fuel. 4/ Designated high-sulfur fuel.

5/ Flash point by Cleveland open cup method, A.S.T.M. D92-52.

6/ Not within specification of fuels for this grade, figure not included in average.

TABLE 10.—Analyses of grade 6 burner fuel oils, 1955 (Cont.)

Western region: Districts L, M, and N

Item	Distributed in districts 1/	Gravity	Flash point	Viscosity, Furol at 122° F.	Pour point	Sulfur content	Carbon residue Ramsbottom 2/	Ash	Water and Sediment
		A.S.T.M. D287	A.S.T.M. D93	A.S.T.M. D88	A.S.T.M. D97	A.S.T.M. D129	A.S.T.M. D524	A.S.T.M. D482	A.S.T.M. D96
		° A.P.I.	°F.	sec.	°F.	percent	on 100 percent sample, percent	percent	vol. %
322	L,M	10.4	214	107.0	25	0.90	13.5	0.04	0.20
323	L,M	9.6	214	170.0	30	.95	14.2	.05	.20
324	L,M,N	8.5	230	175	35	1.35	17.6	.06	.2
325	L,M,N	9.0	210	100	5	1.25	15.9	.04	.2
326	L,M,N	8.0	220	160	30	1.37	17.3	.05	.2
327	L,M,N	10.5	214	236	40	1.53	18.1	.05	.3
328	L,N	9.3	172	109.0	20	1.79	13.1	.06	.10
329	L,N	8.1	196	174.0	30	1.70	14.1	.06	.20
330	M,L	8.8	196	169	25	.95	-	.05	.3
331	N	9.5	158	200	30	4.4	18	.1	.2
332	N	15.6	200	110	30	.5	4.56	.01	.1
333	N	14.5	200	171	35	.5	4.56	.01	.3
334	N	9.0	180	200	30	1.50	12.0	.11	.20
335	N,L	8.9	178	173	30	1.68	-	.07	.1
336	N,L,M	10.1	185	110	20	1.5	14	.06	.1
337	N,L,M	8.0	180	180	25	1.7	15	.06	.2
338	N,M	9.4	168	106.0	15	.92	13.7	.02	.10
339	N,M	7.9	184	202.0	25	.86	16.0	.03	.10
340	N,M,L	12.1	172	120	20	4.0	12	.07	.03
341	N,M,L	10.5	180	180	25	4.4	13	.08	.1
308	H,K,L,I	14.9	420	115	60	5.25	5.7	.07	Trace
309	H,L	9.0	150	70	25	2.4	13.7	.03	.2
310	H,L,K	7.8	200	146.1	35	2.50	3.75	.015	.9
311	H,L,K,F	8.4	250	89.6	20	3.46	14.2	.026	.2
Average (24 samples)		9.9	-	148.9	-	1.97	12.91	0.051	0.20
Minimum		7.8	150	70	5	0.5	3.75	0.01	0.03
Maximum		15.6	420	236	60	5.25	18.1	.11	.9

1/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of the fuel. Fuels listed above the lines separating items 341 and 308 in the Western region are generally sold in greatest volume in those respective regions. The fuels listed below the lines are generally sold in lesser volumes in the respective regions than in some other regions.

2/ Some of the determinations were made by the Conradson method, A.S.T.M D189-52, and the data were converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

Bureau of Mines
Information Circular 7731

TUNGSTEN POTENTIAL IN THE SAN JUAN AREA, OURAY, SAN JUAN, AND SAN MIGUEL COUNTIES, COLO.

BY CARL BELSER

United States Department of the Interior — January 1956

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* * * * * * * * * Information Circular 7731

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
Thos. H. Miller, Deputy Director

January 1956

TUNGSTEN POTENTIAL IN THE SAN JUAN AREA OURAY, SAN JUAN, AND SAN MIGUEL COUNTIES, COLO.

by

Carl Belser 1/

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1/ Mining engineer, Bureau of Mines, Region III, Denver, Colo.

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CONTENTS (Con.)

ILLUSTRATIONS

INTRODUCTION AND SUMMARY

This report on tungsten in Ouray, San Juan, and San Miguel Counties, Colo., is one of a series describing results of studies on the tungsten potentialities in Region III, Bureau of Mines. The San Juan tungsten deposits occur in an area of 250 square miles, centering near the common corner of Ouray, San Juan, and San Miguel Counties (fig. 1).

Field work supporting these studies was done in May 1954. Bureau of Mines reports prepared from investigations made during World War II and under the Defense Production Act of 1950 were reviewed.

In the early eighties a peculiar, brownish mineral was noted in the Adams lode on Bonita Mountain, San Juan County, and samples sent to Freiberg, Germany, were identified as hübnerite (Mn, Fe)WO_4. This mineral was later found in Dry Gulch on Cement Creek, San Juan County, in strong, quartz-lead veins (Ohio, Dawn of Day, Minnesota, Sunshine, and Galtie Boy mines).

Production of hübnerite began in or just before 1899. C. A. Cooper (4)[2/] wrote: "Several tungsten properties are now being worked." Ore containing 70 percent WO_3 had increased in price from $85 a ton to $350 a ton or $5 a unit in 1899. Cooper further stated that tungsten was known to occur in several of the developed mines and in a dozen or more prospects.

The first recorded production from the San Juan region was in 1900, when 11,000 pounds of concentrate containing 69.5 percent WO_3 was shipped. This ore was concentrated in the Fisher mill near the mouth of Dry Gulch. A small amount of tungsten was mined during 1901-8. In 1908 the Eveline tunnel was driven to cut the Dry Gulch tungsten veins at increased depth. The tungsten encountered reportedly was rather scattered, although of good grade. Tungsten mining remained dormant from 1908 until 1915, when an increase in price stimulated by World War I led to renewed activity. In 1916-17 Louis Shaffer operated a mill near the portal of the Yukon (Uncle Sam) tunnel, principally on ores from mines in Dry Gulch, and produced concentrates valued at $140,000. Hand-sorted ore from several mines also was shipped during this period. The Gold Hub Mining Co. constructed a mill at the portal of the Yukon (Uncle Sam) tunnel in 1936 to treat hübnerite ore from the Uncle Sam vein encountered in the tunnel, but the operation was reported to be unprofitable. Hand-sorted ore from various mines was shipped during World War II. In 1951 Williams and Welby installed machinery in the old Gold Hub mill and produced concentrates from the Dawn of Day-Ohio dump ores. The Silver Bell Mines Co. operated a small mill at Ophir, San Miguel County, in 1953.

2/ Underlined numbers in parentheses refer to items in the Bibliography at the end of this report.

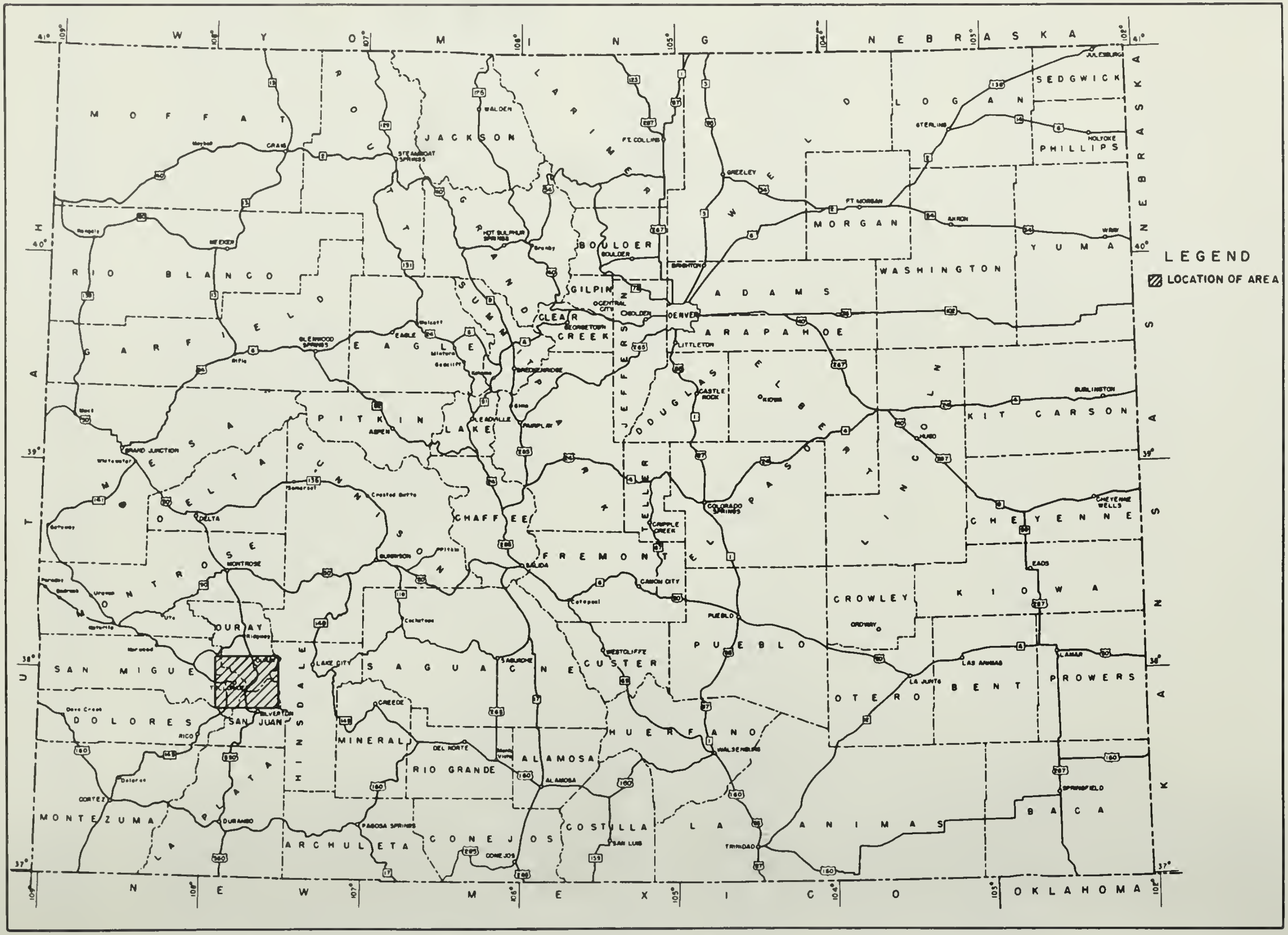

Figure 1. - Location of the San Juan tungsten area, Ouray, San Juan, and San Miguel Counties, Colo.

The 1953 production for the area was 6,466 pounds (323 short-ton units) of tungsten trioxide, and the total production from 1900 through 1953 is estimated as 350,346 pounds (17,517 short-ton units) of tungsten trioxide. Indicated and inferred reserves are estimated as 72,000 tons containing 1.36 percent WO_3.

Production has been recorded from at least 24 mines, and the occurrence of tungsten has been reported at 17 other properties. During 1953, 5 properties mined tungsten ore and 2 mills were in operation. Of the 24 mines that have produced tungsten, 6 are in condition for immediate operation, 3 require improved ventilation, and 15 need considerable rehabilitation. Two mines which operated in 1954 received financial assistance from the Defense Minerals Exploration Administration.

PHYSICAL FEATURES

Near the center of the San Juan tungsten region, 3 mountainous ridges join at radiating angles of approximately 120°. These ridges form the boundary lines between Ouray, San Juan, and San Miguel Counties, and from the common point of intersection the drainage is north to the Uncompahgre River, west to the San Miguel River, and south to the Las Animas River (fig. 2). All three of these streams eventually flow into the Colorado River. To the southeast but outside the known tungsten region the drainage is to the Rio Grande. The region is extremely mountainous, containing narrow valleys and deep canyons. Altitudes range from a low of 7,721 feet at Ouray to over 14,000 feet.

Annual precipitation ranges from a low of 25 inches at Silverton to a high of 50 inches at Red Mountain. Snowfall is heavy and winters are severe, and with the exception of a few mines situated near the main highways access roads to small operations cannot be maintained in the winter.

The access roads, ranging from good to poor, extend to 12 of the 24 mines from which production has been made. Local material and equipment supply points are Silverton (population 1,375), Telluride (population 1,089), and Ouray (population 1,101). Denver and Rio Grande Western railroad facilities are available at Ridgeway from which good, all-weather highways extend 10 miles to Ouray, 34 miles to Silverton, and 40 miles to Telluride.

Native timber abounds in the region, but most mining timber is transported from other regions. Service lines of the Western Colorado Power Co. traverse the region.

Adequate labor and housing are available in Ouray, Silverton, and Telluride. Prevailing wages range from $1.50 to $2.00 an hour.

GENERAL GEOLOGY

The basement rocks of the area are Archaen schists and gneisses covered by about 8,000 feet of steeply tilted Algonkian quartzites and slates, which in turn are covered by about 3,600 feet of flat-bedded sedimentary formations of Cambrian, Devonian, and Carboniferous age. The sedimentary rocks are capped with approximately 6,200 feet of flat-dipping volcanic flows and tuffs of Tertiary age. The Silverton volcanic series, approximately 4,500 feet thick, is in the center of the Tertiary flow rocks and contains the principal known ore deposits. The Silverton series consists mainly of rhyolite, latite, and andesite flows, tuffs, and breccias. Igneous stocks and dikes have intruded the flat-dipping volcanic series.

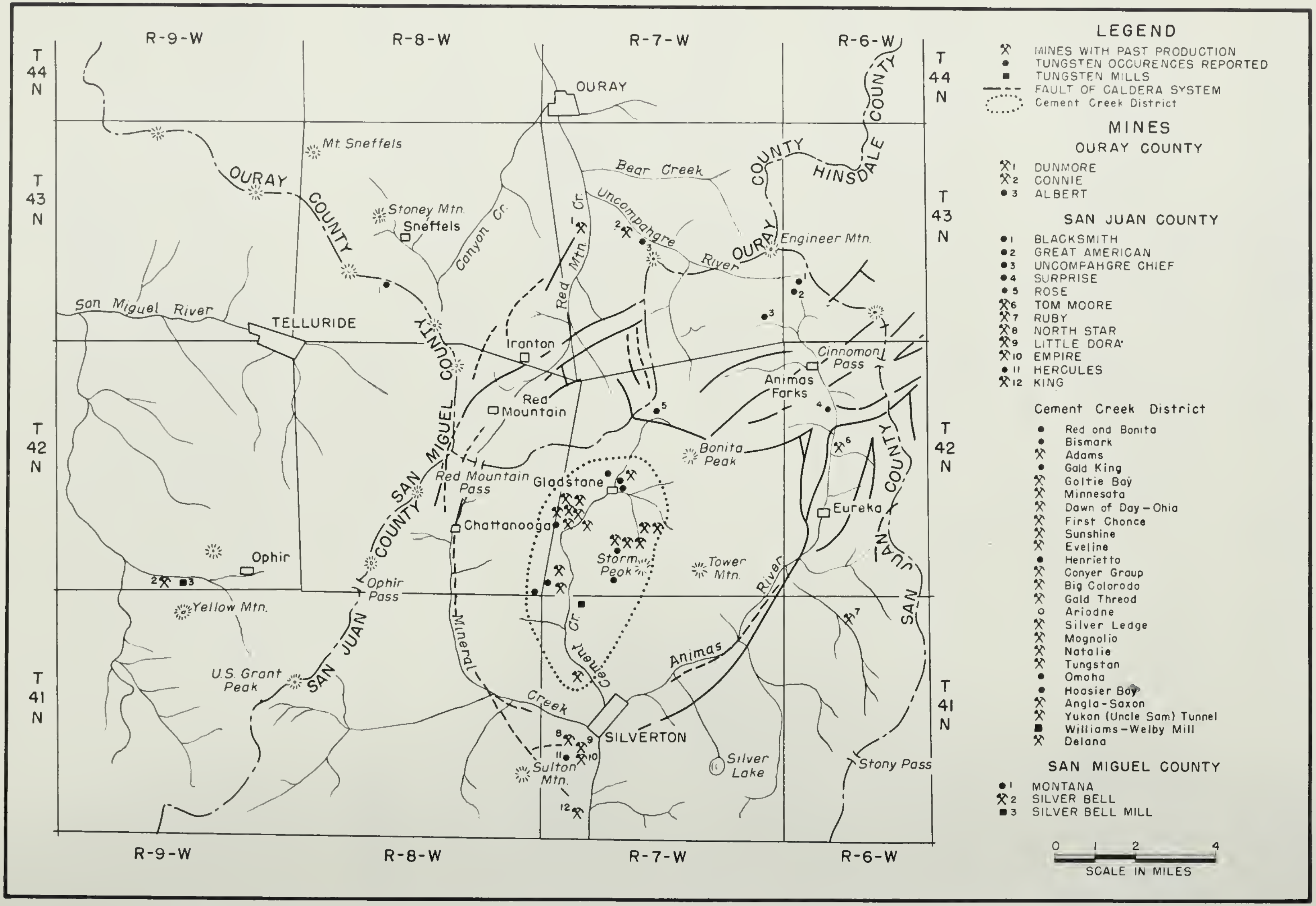

Figure 2. - Location of known and reported tungsten occurrences in Ouray, San Juan, and San Miguel Counties, Colo.

A down-fault block, more or less circular and about 8 miles in diameter, is situated in the Silverton area. The east, south, and west sides of the block closely follow or parallel the Animas River and Mineral Creek (fig. 2). This fault block has a downward displacement of 1,500 to 2,000 feet and has been called the Silverton caldera (1, 2, 3, 7, 10). Stocks of monzonite and diorite have been intruded into a ring-fault zone. The known tungsten deposits are adjacent to or within the caldera or occur in or near igneous stocks or strong vein systems. The ore mineral hübnerite is often associated with fluorite. A small amount of scheelite occurs in some of the veins.

DESCRIPTION OF DEPOSITS

Tungsten has been mined from 24 properties and is known to occur in 17 others (fig. 2). The name, location (fig. 2), and ownership are as follows:

Mine	Location	Ownership
	Ouray County	
Dunmore	Sec. 17, T. 43 N., R. 7 W.	E. E. Eggleston.
Connie	Sec. 17, T. 43 N., R. 7 W.	Do.
Albert	Sec. 17, T. 43 N., R. 7 W.	Do.
	San Juan County	
Blacksmith	Sec. 30, T. 43 N., R. 6 W.	Merle Brush.
Great American	Sec. 30, T. 43 N., R. 6 W.	Do.
Uncompahgre Chief	Sec. 36, T. 43 N., R. 7 W.	London, Inc.
Surprise	Sec. 8, T. 42 N., R. 6 W.	Bently McMullen.
Tom Moore	Sec. 17, T. 42 N., R. 6 W.	Great Divide Mining & Milling Co.
Rose	Sec. 10, T. 42 N., R. 7 W.	Laurette Giroux.
Ruby	Sec. 5, T. 41 N., R. 6 W.	Angelo Dahla.
North Star	Sec. 19, T. 41 N., R. 7 W.	Mystery Gold Mining Co.
Little Dora	Sec. 17, T. 41 N., R. 7 W.	Do.
Empire	Sec. 19, T. 41 N., R. 7 W.	Do.
Hercules	Sec. 19, T. 41 N., R. 7 W.	Do.
King	Sec. 28, T. 41 N., R. 7 W.	San Juan County.
	San Juan County - Cement Creek district	
Red and Bonita	Sec. 16, T. 42 N., R. 7 W.	Atlas Mining Co.
Bismark	Sec. 16, T. 42 N., R. 7 W.	C. Maguire.
Adams	Sec. 16, T. 42 N., R. 7 W.	T. A. and D. A. Mahoney.
Gold King	Sec. 15, T. 42 N., R. 7 W.	San Juan Gold Mining Co.
Galtie Boy	Sec. 17, T. 42 N., R. 7 W.	F. L. Ross and E. M. Bacon.
Minnesota	Sec. 20, T. 42 N., R. 7 W.	Do.
Dawn of Day - Ohio	Sec. 20, T. 42 N., R. 7 W.	Victor Steele.
First Chance	Sec. 20, T. 42 N., R. 7 W.	Thomas Burgess.
Sunshine	Sec. 20, T. 42 N., R. 7 W.	Charles Bacon.
Eveline	Sec. 20, T. 42 N., R. 7 W.	Eveline M. and M. Co.
Henrietta	Sec. 19, T. 42 N., R. 7 W.	Blue Bird Mining Co.
Conyer group	Sec. 29, T. 42 N., R. 7 W.	Albert Conyers Est.
Big Colorado	Sec. 28, T. 42 N., R. 7 W.	F. B. Brown.
Gold Thread	Sec. 28, T. 42 N., R. 7 W.	Whised Lanning.
Ariadne	Sec. 28/35, T. 42 N., R. 7 W.	Ariadne Corp.
Silver Ledge	Sec. 27, T. 42 N., R. 7 W.	Victor Steele.
Magnolia	Sec. 27, T. 42 N., R. 7 W.	Silver Bay Mines, Inc.
Natalie	Sec. 27, T. 42 N., R. 7 W.	Do.
Tungsten	Sec. 30, T. 42 N., R. 7 W.	John Bendino.
Omaha	Sec. 31, T. 42 N., R. 7 W.	Unknown (N. P.).

Mine	Location	Ownership
San Juan County - Cement Creek district (Con.)		
Hoosier Boy.............	Sec. 25, T. 42 N., R. 8 W.	Great Divide Mining Co.
Anglo-Saxon	Sec. 31, T. 42 N., R. 7 W.	San Juan Gold King Co.
Yukon tunnel (Uncle Sam)	Sec. 32, T. 42 N., R. 7 W.	Ariadne Corp.
Delano	Sec. 7, T. 41 N., R. 7 W.	Unknown.
	San Miguel County	
Montana	Sec. 28, T. 43 N., R. 8 W.	Idarado Mining Co.
Silver Bell	Sec. 33, T. 42 N., R. 9 W.	Silver Bell Mines Co.

Ouray County

A brief description of the mines and prospects in the region follows:

Dunmore Mine (7 and 8)

The Dunmore mine is on the west side of Red Mountain Creek and about 5 miles by road from Ouray. Surface facilities consist of 2 small buildings, 2 ore bins, and a 900-foot, unusable aerial tramway, which has a terminal on U. S. Highway 550. The mine is developed by 2 adits at altitudes of 9,090 and 9,264 feet. The vein, which is about 100 feet wide throughout its 800 feet of exposed length, strikes N. 75° W. and dips 80° SW. Near the north wall is a 1- to 3-foot quartz streak. The south half of the vein is mostly barren, siliceous material. In this area two chimneylike deposits occur, which were probably formed by a number of fissures, striking N. 10° W., and crossing the Dunmore vein. One chimney 8 to 12 feet wide and 40 to 50 feet long contains hübnerite, and the other about 30 by 40 feet across contains hematite and copper sulfides. The country rock consists of Uncompahgre quartzite and Algonkian shale. The mine was first worked for gold. Tungsten ore was mined by the Frantz Bros. in 1937, and production has continued intermittently since that time.

Connie Mine

The Connie mine (7) is on the Dunmore fault about 4,000 feet southeast of the Dunmore mine at an altitude of 9,726 feet and is reached by trail from U. S. Highway 550. The vein is 15 feet wide and has quartzite walls with a 5-foot central rib of barren quartz. The strike of the vein is N. 78° W. and the dip is 80° SW. Country rock on the north side of the vein is Uncompahgre quartzite and to the south, San Juan tuff. The vein is developed by three short adits. Several tons of hand-sorted hübnerite ore have been produced as a byproduct in the development of a small lead ore body.

Albert Mine

The Albert prospect (7) is in Uncompahgre Canyon about 6 miles from Ouray and is located on the Dunmore vein fault about 7,000 feet southeast of the Dunmore mine. This fault has been traced on the surface for 3 miles and at the Dunmore mine reaches 100 feet in width in the underlying Uncompahgre formation but narrows to a few feet in the San Juan formation. The vertical displacement occurring in pre-San Juan time is about 2,800 feet and in post-San Juan time about 80 feet, the south side block being downward. The general strike of the fault is N. 75° W., and the dip is 80° SW. East of Red Mountain Creek, on the south side of the fault, a narrow intrusion of traprock can be traced for 1,200 feet. The prospect, at an altitude of about 9,760 feet, is developed by a few shallow workings. The surface rock is

San Juan tuff. The vein strike is N. 70° W. and the dip is 75° SW. Some hübnerite occurs in the vein, but no ore has been shipped.

San Juan County

Blacksmith Mine

The Blacksmith mine (7) is on the south side and near the head of the Uncompahgre River at an altitude of about 12,000 feet. The property is about 15 miles by road northeast of Silverton and is on the northeastward end of a strong vein system that has an average strike of N. 50° E. and can be followed to the southwest for over 7 miles. About 6,000 feet southwest on the Del Norte claim the vertical displacement along the latite-andesite vein contact is 40 feet, the downward side being southeast. The vein at the Blacksmith mine strikes N. 60° E. and carries base-metal ores and, in places, hübnerite. Country rock is pyroxene andesite. Only a limited amount of development work has been done.

Great American Mine

The Great American mine (7) is on the south side and near the head of the Uncompahgre River 15 miles by road from Silverton at an altitude of 12,200 feet. The mine is on the same vein and has the same end-claim line as the Blacksmith lode. The vein strikes N. 60° E. through pyroxene andesite and reportedly contains a small amount of hübnerite with considerable base-metal sulfides.

Uncompahgre Chief Mine

The Uncompahgre Chief mine (70 is on the north side of Burrows Creek, a tributary of the North Fork of the Animas River, about 14 miles by road from Silverton at an altitude of 12,017 feet. The vein, striking N. 30° E. through Burns latite, is probably an extension of the Blacksmith vein. The principal vein minerals are sphalerite, tetrahedrite, and galena, with a quartz gangue, although some hübnerite is scattered through the quartz. Mine workings consist of several small shafts and adits and a few shallow pits and trenches. The mine has yielded hübnerite specimens, but no tungsten ore has been shipped.

Surprise Mine

The Surprise mine is on a claim recently located on the west side of the Animas River 11 miles northeast of Silverton at an altitude of about 11,000 feet. The vein strikes northeastward, and the country rock is Burns latite. It contains hübnerite, but no tungsten has been produced from the property.

Tom Moore Mine

The old Tom Moore workings (8) are on the east side of the Animas River 10 miles northeast of Silverton by road at an altitude of 11,500 feet. The vein has been developed by 5 adits, the lowest of which (altitude 10,400 feet) is 1,500 feet long. The vein strikes N. 50° E. through Eureka rhyolite and is heavily mineralized with base-metal sulfides. A quartz band 4 to 12 inches in width on the footwall contains hübnerite. The hübnerite-bearing band has been left on the wall except near the breast where it was mined, sorted, and shipped. The large dump contains hübnerite crystals. The vein can be traced for over a mile. Across the river to the south hübnerite stringers can be seen in the cliff face.

Rose Mine

The Rose mine is at the head of Cement Creek near the Cement Creek Monument 11 miles from Silverton by road and trail at an altitude of 12,200 feet. The vein strikes N. 40° E. through pyroxene andesite and may be part of the Blacksmith-Uncompahgre vein system. A few short mine workings are accessible. A small amount of hübnerite ore is reported to have been shipped from the property.

Ruby Mine

The Ruby mine (8) is on the west side of Maggie Gulch 9 miles by road from Silverton at an altitude of 11,000 feet. A vein strikes N. 5° W. through Eureka rhyolite and reportedly is traceable for 3 miles on the surface. A stock of quartz monzonite is situated to the west and would be cut by the vein about half a mile to the northwest. The mine is developed by a 270-foot adit. Approximately 14 tons of 10-percent ore was produced in 1942 from an ore shoot 3 feet wide and 15 feet long. The mine was operated during the summer of 1953, and a small amount of hübnerite ore was produced.

North Star Vein

The North Star vein (8) is near the northwest end of the Mystery Gold Mining Co. group of claims and was worked through the North Star tunnel. This tunnel is just south of Silverton at an altitude of 9,430 feet, but it is now inaccessible. The North Star vein strikes about N. 30° W. through a large stock of quartz-monzonite. Hübnerite occurs with sulfide ores, but no tungsten ore has been shipped.

Little Dora Mine

The Little Dora Vein (8) is one of a group owned by the Mystery Gold Mining Co., which is south of Silverton. It strikes N. 20° W. through a large quartz-monzonite stock. Hübnerite occurs throughout the ore. A substantial quantity of tungsten has been produced, including 1 shipment of 19 tons of 35-percent hübnerite ore. The tungsten ore in the Mystery group of veins is darker than that from the Dry Gulch region, and the tungsten mineral might be wolframite.

Empire Vein

The Empire vein (8) is in a group of 45 claims covering the Empire, Champion, and North Star groups on Sultan Mountain, south of Silverton. The property contains many veins and has been developed by several adits. The more important are:

Name	Altitude Feet
Pittsburgh	9,240
Empire	9,400
North Star	9,430 (caved)
Boston	9,600
Jennie Parker	9,670
Ricker	9,850

The group has been worked as a gold-silver-lead mine but has produced some tungsten. The veins are within a large stock of quartz-monzonite and strike 15° N. 35° W. Tungsten has been known to occur in veins of the Mystery Gold Mining Co. group of claims since early in 1900. Veins in this area generally carry complex sulfides

and small quantities of hübnerite. The Empire vein, striking about N. 15° W., contains an 8-inch band of hübnerite ore about 50 feet long from which 3 carloads of 26-percent ore were shipped from 1939 to 1941.

Hercules Vein

The Hercules vein (8) is the southeastern extension of the Little Dora vein, which is on the northeast side of Sultan Mountain south of Silverton. The vein strikes N. 30° W. through a large quartz-monzonite stock and contains some hübnerite ore. No shipments have been made. The Hercules and Little Dora properties are part of the holdings of the Mystery Gold Mining Co.

King Mine

The King mine (8) is on the west side of the Animas River 2 miles south of Silverton at an altitude of 9,900 feet. The vein strikes N. 5° E. through pre-Cambrian schists and gneisses east of a small stock of intrusive porphyry. It appears to be the southwest continuation of the Mineral Creek fault. The mine was principally worked for gray copper ore, but some tungsten has been produced.

San Juan County - Cement Creek District

Red and Bonita Mine

The Red and Bonita mine is on the east side of the north fork of Cement Creek about 9 miles by road from Silverton at an altitude of 10,900 feet. The mine is about 2,000 feet southwest of the Adams lode and has been worked extensively as a gold mine; however, the workings are caved. The vein strikes northeast and is reported to contain scattered deposits of hübnerite; hübnerite float has been found on the surface. No tungsten has been produced.

Bismark Mine

The Bismark mine is on the south fork of Cement Creek 9 miles by road from Silverton at an altitude of about 11,400 feet. Mine workings are caved. The Bismark vein, which strikes abtout N. 55° W., is in pyroxene andesite of the Silverton volcanic series. A small amount of honey-colored hübnerite is reported to have been produced from the property.

Adams Mine

The Adams lode (8) is on the east side of Cement Creek about 9 miles by road from Silverton at an altitude of 11,300 feet. The last 1,500 feet to the mine is over a poor trail. Hübnerite was identified in the Adams lode in the early eighties and was first mined in 1899. A substantial quantity of tungsten was produced during World War I. The vein is 3 to 4 feet wide, strikes N. 10° E., dips 80° SE., and contains quartz with specks of galena, pyrite, fluorite, and hübnerite. The hübnerite is reported to have occurred in bands up to 18 inches wide. Country rock is pyroxene andesite. This property, which may be near the southwest extension of the Bonita fault, is developed by two short adits and a deep surface cut but has been idle for a long time. Mine dumps appear to contain a milling grade of tungsten.

The owners have applied to the Defense Minerals Exploration Administration for assistance in exploring the deposit.

Gold King Mine

The portal of the Gold King tunnel (8) is at Gladstone on Cement Creek 8 miles by road from Silverton at an altitude of 10,600 feet. The tunnel and upper workings (altitude 12,150 feet) are inaccessible. The vein strikes northeast through pyroxene andesite. This mine has produced considerable gold. In 1908 hübnerite was found in sheaflike crystals up to 3 inches in length and partly incrusted with quartz and fluorite in vugs along th vein. No tungsten has been produced.

Galtie Boy Mine

The Galtie Boy mine (8) is in Dry Gulch on the west side of Cement Creek 8 miles from Silverton at an altitude of about 10,800 feet. Originally the mine was worked for gold, silver, copper, and lead, but later tungsten was produced. An adit driven about 200 feet below the old workings, which are inaccessible, exposed 2 ore shoots, one 2.4 feet wide and 10 feet long and the other 1.7 feet wide and 60 feet long. The vein strikes northwestward through rocks of the Silverton volcancic series.

Minnesota Mine

The Minnesota mine (8) is between the Dawn of Day-Ohio and Galtie Boy mines at an altitude of about 10,900 feet. A short access road is needed to connect this property with the Dawn of Day-Ohio road. The vein strikes N. 60° W. through country rock consisting of Tertiary flows of the Silverton volcanic series. The vein has been stoped to the surface from a short, caved adit. The tungsten ore mineral is hübnerite, which occurs with lead and zinc in a quartz vein. An appreciable quantity of tungsten has been produced, and some indicated ore remains. A Defense Minerals Exploration Administration project has been approved for exploration of the property.

Dawn of Day-Ohio Mine

The Dawn of Day-Ohio property (8) consists of two claims end to end on the same vein. The mine is in the Dry Gulch area on the west side of Cement Creek 8 miles from Silverton by road and at an altitude of 10,900 feet. The vein strikes N. 60° W., dips 80° NE., and cuts through rocks of the Silverton volcancic series. It is 2 to 4 feet wide and contains hübnerite and base-metal sulfides. The Dawn of Day-Ohio is reported to contain a tungsten ore shoot 8 inches wide and 120 feet long of 40-percent WO_3 content. The mine has been developed by three short adits, which are caved. Almost all of the upper dump and part of the stope fills have been milled recently. The mine, which was worked for tungsten early in 1900 and during both World Wars, has been one of the most productive in the area.

First Chance Mine

The First Chance mine is in the Dry Creek area on the west side of Cement Creek and about 8 miles from Silverton. The vein strikes northwest in country rock of the San Juan volcanic series. The First Chance property was located recently by Thomas Burgess, who produced a small amount of tungsten from the property in 1953.

Sunshine Mine

The Sunshine mine is in Dry Gulch on the west side of Cement Creek 8 miles from Silverton by road at an altitude of about 11,000 feet. A vein strikes northwestward through rocks of the Silverton volcanic series. The Sunshine claim is adjacent to

the Ohio claim. Tungsten ore occurs in a narrow band, and a small amount of hübnerite ore has been produced.

Eveline Mine

The Eveline mine is in Dry Gulch on the west side of Cement Creek 8 miles by road from Silverton at an altitude of 11,000 feet. The vein strikes N. 70° W. through the San Juan volcanic series. Tungsten was discovered on the vein before 1900, when a small amount was sold. The Eveline tunnel was driven from the foot of Dry Gulch in 1908 to intersect the known tungsten deposits. The mineral found was rather scattered but of good concentrating grade.

Henrietta Mine

The Henrietta mine is at the head of Prospect Gulch 11 miles by road from Silverton at an altitude of about 11,700 feet. The mine, which is developed by a lower adit from Dry Gulch, has been worked chiefly as a gold mine. The vein strikes N. 25° E. through rock of the Silverton volcanic series. Hübnerite reportedly occurs in the vein in small quantities, but none has been produced.

Conyer Group

This group of three claims (8) is near the mouth of Dry Gulch on the east side of Cement Creek 7 miles from Silverton by road at an altitude of 10,500 feet. Cement Creek may follow along hidden faults in the Silverton caldera, and two of these faults may intersect just above Dry Gulch. Such an occurrence would help to explain the many tungsten-bearing veins in this vicinity. The Conyer vein is in the Silverton volcanic series of Tertiary age. The Conyer property was a producer early in 1900 and during World War I, when several tons of ore assaying 30 percent WO_3 was mined. The mine reportedly has reserves of tungsten ore.

Big Colorado Mine

Big Colorado mine is on the west side of the south fork of Cement Creek 10 miles by road from Silverton at an altitude of about 11,100 feet. A vein striking N. 20° E. through pyroxene andesite is developed by a short crosscut adit with side drifts. Originally, the mine was worked for gold; later hübnerite specimens were found, but the property has not produced any tungsten ore.

Gold Thread Mine

The Gold Thread mine is on the west side of the south fork of Cement Creek 10 miles by road from Silverton at an altitude of about 11,000 feet. It is adjacent to the Big Colorado mine. The Gold Thread vein, striking N. 20° E. through pyroxene andesite flows of Tertiary age, is 18 inches wide and contains a persistent hübnerite streak 1 to 3 inches wide. Small lenses of hübnerite were seen in the vein in the 300-foot tunnel. Hübnerite was observed scattered throughout the dump, and tungsten was reported to have been produced during World War I.

Ariadne Mine

The Ariadne mine is on the east side of the north fork of Cement Creek near the head of Cascade Creek at an altitude of about 11,500 feet. An old wagon road 2 miles long connects the property with the Cement Creek road 6 miles northwest of Silverton. The Ariadne vein is about 60 feet wide and strikes N. 30° E. through

pyroxene andesite. The vein is developed by a short crosscut adit with drifts along the walls from which complex sulfide ores were mined. Hübnerite occurs in places, but it has never been mined.

Silver Ledge Vein

The Silver Ledge vein is reached through two adits, both caved. The lower Occidental adit reportedly cuts the Silver Ledge vein at 300 feet, the Magnolia vein at 900 feet, and the Natalie vein at about 5,000 feet from the portal. The portal of the lower Silver Ledge adit is at an altitude of 11,000 feet and is 10 miles from Silverton by road. The upper adit dump contains a number of hübnerite specimens. The vein, striking N. 4° W., is in pyroxene andesite. It reportedly has been explored by 2,000 feet of drift and contains a persistent, narrow, tungsten-bearing zone. The mine was operated during the nineties as a gold mine. Some hübnerite ore has been shipped from the property.

Magnolia Vein

The Magnolia vein was reached through the Occidental adit, which is on the east side of the south fork of Cement Creek 10 miles by road from Silverton at an altitude of about 11,000 feet. The vein has been developed by 2,500 feet of drifts, and reportedly, a persistent,narrow, tungsten-bearing zone occurs in the vein. A small quantity of tungsten has been produced. The adit is inaccessible.

Natalie Vein

The Natalie vein, which outcrops at an altitude of 12,000 feet, is reached through the Occidental adit. It strikes N. 40° W. in pyroxene andesite. Spots containing good hübnerite ore have been found on the surface, and the vein encountered in the workings below reportedly contains considerable hübnerite. A small amount of tungsten ore has been produced from the mine.

Tungsten Mine

The Tungsten mine is in Minnesota Gulch on the west side of Cement Creek 6 miles from Silverton by road at an altitude of 10,500 feet. The vein on the property strikes N. 10° W. through Tertiary rock of the Silverton volcanic series. A small amount of hübnerite ore has been shipped from the property.

Omaha Mine

The Omaha mine is on an unpatented claim up Ohio Creek, a tributary of Cement Creek from the west and is about 5 miles from Silverton by road and trail. Good specimens of hübnerite reportedly have been taken from the property, but no shipments have been made.

Hoosier Boy Mine

The Hoosier Boy mine is at the head of Fairview Gulch on the west side of Cement Creek 8 miles by trail and road from Silverton at an altitude of about 12,000 feet. The Hoosier Boy vein, striking N. 25° E. through rocks of the Silverton volcanic series, probably is related to the Henrietta vein system. Hübnerite is said to occur in the vein, but no shipments have been made. Mine workings are limited. According to F. L. Ross, all veins in this area contain some hübnerite.

Anglo-Saxon Mine

The Anglo-Saxon mine (8) is in Porcupine Gulch on the west side of Cement Creek at an altitude of about 10,300 feet. It is 5 miles northwest of Silverton over a county road that parallels Cement Creek to within a short distance of the property. The vein strikes N. 60° E. through rocks of the Silverton volcanic series. Some ore was produced during World War I.

Yukon Tunnel (Uncle Sam)

The Yukon tunnel (8), which cuts the Uncle Sam vein, is a long crosscut adit on the east side of Cement Creek 4 miles from Silverton by road at an altitude of 10,000 feet. The Uncle Sam vein is strong and strikes N. 25° E. through Eureka rhyolite. It is probably the same vein as the Ariadne, which crops out 6,000 feet farther northeast. Base-metal sulfide mineralization is found near both walls. Tungsten occurs as hubnerite with some scheelite and is found with galena, sphalerite, and pyrite in a zone 6 to 18 inches wide and about 100 feet long. High-grade specimens of hübnerite ore were obtained from the ore shoot by the Gold Hub Mining Co., who built a mill in 1936 to concentrate the hübnerite ore. Large pieces of hübnerite float are said to have been found on the surface about 1,500 feet vertically above the Yukon tunnel workings. These workings are not accessible at the present time. A small amount of tungsten concentrate has been produced.

Delano Mine

The Delano mine (8) is on the west side of Cement Creek at an altitude of 9,800 feet and 2 miles by road from Silverton. The northerly striking vein, which is 6 feet wide and cuts through rocks of the Silverton volcanic series, was developed during 1910 and worked during World War I. Production came from several small ore shoots, the largest of which was about 30 feet long. Reportedly, 5 tons of 61-percent WO_3 concentrate was made at the Shaffer mill from one lot of ore. A hübnerite band, 2 to 6 inches wide is said to have been developed for 1,300 feet.

San Miguel County

Montana Vein

The old gold-lead-zinc workings on the Montana vein are at the head of Marshall Creek at an altitude of 12,500 feet. The vein has been worked extensively and is opened by the Revenue tunnel (altitude 10,650 feet), the Argentine tunnel (altitude 10,590 feet), and a new adit from Pandora (altitude 9,100 feet). It is the northwestern part of Montana-Argentine-Black Bear vein system, one of the strongest in the San Juan region. The vein strikes N. 15° W. through rocks of the igneous Intermediate and San Juan series and through the underlying sedimentary rocks. This vein system can be traced directly to Stony Mountain, which consists of a gabro diorite stock 2 miles northwest of the Montana claim. The vein contains considerable base-metal sulfides, gold, and silver.

Originally the Montana vein was worked by A. E. Reynolds through the Revenue tunnel. Later the property was sold to the Tom Boy Gold Mining Co. and was worked extensively and then sold to the Telluride Mines Co., which now is part of the Idarado Mining Co. During World War II hübnerite ore from the north end of the Montana workings was hand-sorted and sacked but was not shipped. No known shipments of tungsten ore have been made.

Silver Bell Mine

The Silver Bell group of claims at Ophir contains 2 tungsten-bearing veins, the Ida and Butler, which crop out at altitudes of 10,800 and 10,700 feet, respectively, and are cut by the Mill tunnel adit (elevation 9,550 feet). The Ida vein strikes N. 70° E. and the Butler vein N. 40° E., and they apparently junction or intersect to the southwest. Both veins dip steeply northwest in country rock composed of a large stock of diorite-monzonite. The mine is opened by 6 adits, and in places the veins have been drifted on for 2,000 feet. The veins are about 4 feet wide and contain base-metal sulfides. The footwalls of the veins are paralleled by narrower quartz veins containing wolframite and minor amounts of scheelite. Fifteen samples taken along the Ida vein averaged 1.69 percent WO_3 over a width of 2.5 feet.

This mine has been worked as a gold-silver-copper-lead-zinc property, and the major production was made before 1909. The property was active in 1922-23 and again from 1946 to the present time. Sixty tons of wolframite ore was shipped in 1940 from the Ida vein, and a small mill was erected in 1952 in which wolframite ores from the Ida and Butler veins were concentrated. The mine contains some reserves of hübnerite ore.

ORE RESERVES

Tungsten ore reserves have been estimated for 13 properties.

Ore reserve	Classification	Number of mines	Tons	Percent WO_3	Units WO_3
Ore in place	Inferred	11	50,550	1.6	84,525
Stope fills	do.	3	4,500	.6	2,900
Dumps	do.	7	16,950	.5	10,160
Total inferred ore		13	72,000	1.3	97,585

METALLURGY

Tungsten ores from the San Juan region have been hand-sorted or concentrated by gravity concentration. The remains of old jigs can be seen near the Adams, Dawn of Day-Ohio, and Delano mines. Three concentrating plants, now dismantled, were erected along Cement Creek for concentrating tungsten. Two plants (figs. 3 and 4) were operated during 1953. The tungsten ores are amenable to gravity concentration, but some of them contain considerable base-metal sulfides, which probably would require flotation concentration. Concentrates produced in mills have been of good grade, but all the mills have lacked fine crushing and grinding facilities, and it is doubtful if good recovery was obtained.

Tungsten samples from several mines were collected, and concentration tests were attempted in 1943 by the Bureau of Mines. The sulfide and tungsten ores were found amendable to concentration. After being ground and classified, the sulfides were recovered by flotation, from which the tails were tabled, the tungsten cleaned by magnetic separation, and the tailings and slimes scavenged by flotation. High recoveries were obtained.

At the Silver Bell mine the gold values of the ore are approximately proportional to the tungsten values. The ores of the Tom Moore, Silver Ledge, Natalie, Magnolia, Empire, Hercules, Little Dora, North Star, Ida, Butler, and Uncle Sam veins contain heavy base-metal sulfides. None of these veins, except the Ida and Butler, are being worked at the present time.

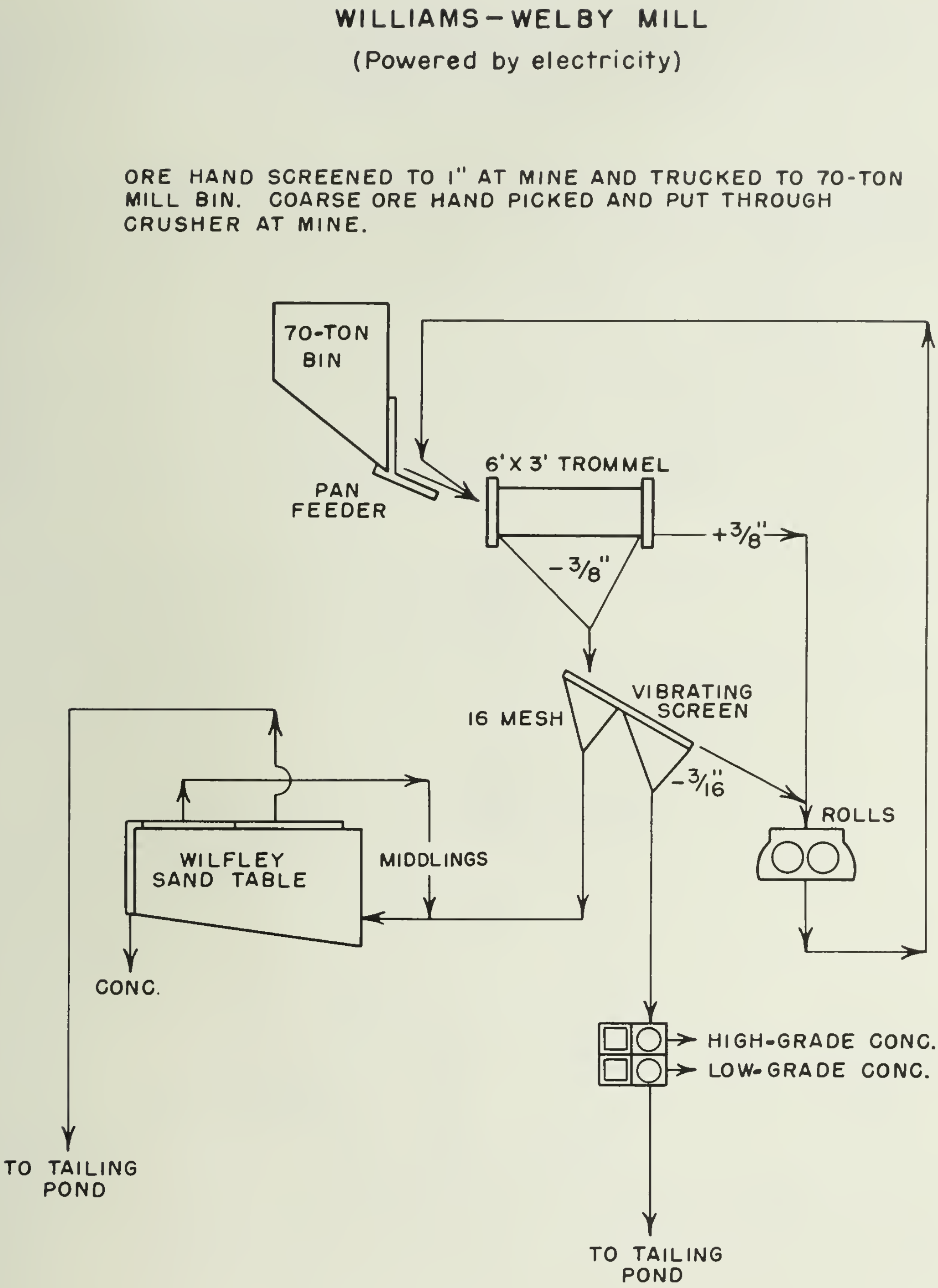

Figure 3. - Flowsheet of the Williams-Welby tungsten mill, San Juan County, Colo.

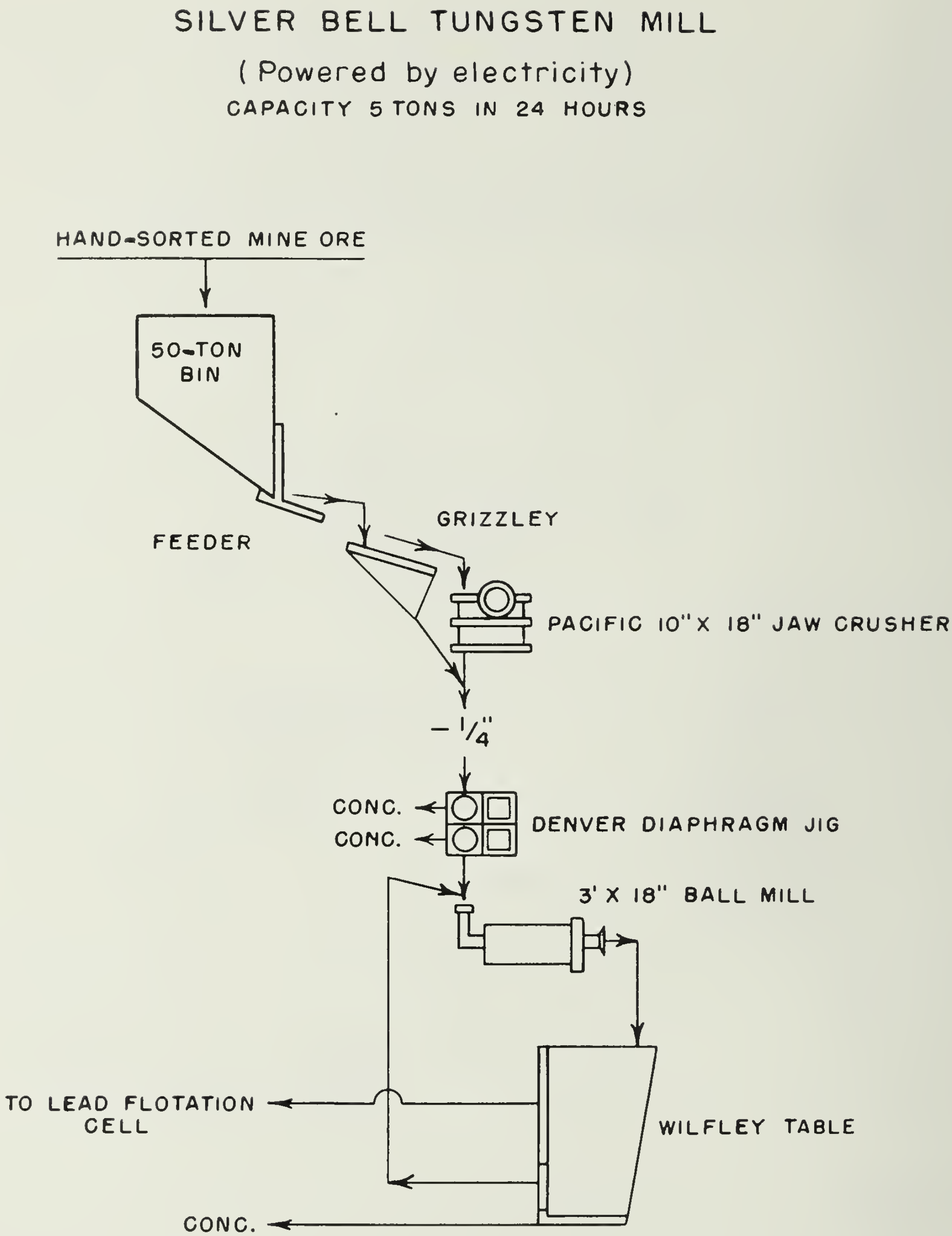

Figure 4. - Flowsheet of the Silver Bell tungsten mill, San Miguel County, Colo.

The Silver Bell tungsten mill discontinued operations in 1953. Available information indicates that the Williams-Welby gravity plant will not be operated during 1955 by the old management.

CONCLUSIONS

Many tungsten mines and prospects in the San Juan region are potential producers. Future production will not be large, but some of the mines could yield a steady, significant output. The tungsten-bearing zones in most of the mines are narrow but can be traced up to several hundred feet in length. The known tungsten workings are small, and individual mine production will probably be on a small scale.

Several veins along Cement Creek contain hübnerite ore that is comparatively free of sulfide of lead and zinc and can be concentrated by simple gravity methods. However, most of the tungsten in the region occurs with sulfide ores, and many mines with both types of ore cannot be exploited for either tungsten or lead and zinc. These mines might be operated profitably if both tungsten and base-metal sulfide concentrates could be recovered.

Several mills in the region are idle but are equipped to process sulfide ores. If one of these mills were modified to include a tungsten unit, incentive to produce would be stimulated considerably.

Future custom-mill operations in the San Juan region should consider including tungsten concentrating facilities.

BIBLIOGRAPHY

1. BURBANK, W. S. Revision of Geologic Structure and Stratigraphy in the Ouray District of Colorado and Its Bearing on Ore Deposition. Proc. Colorado Sci. Soc., vol. 12, No. 6, 1930, pp. 151-232.

2. _____. Structural Control of Ore Deposition in the Red Mountain, Sneffels, and Telluride Districts of the San Juan Mountains, Colorado. Proc. Colorado Sci. Soc., vol. 14, No. 5, 1941, 260 pp.

3. _____. Vein Systems of the Arrastre Basin and Regional Geologic Structure in the Silverton and Telluride Quadrangles, Colorado. Proc. Colorado Sci. Soc., vol. 13, No. 5, 1933, pp. 135-214.

4. COOPER, C. A. Eng. Min. Jour., vol. 67, 1899, p. 499.

5. GROSS, WHITMAN, HOWE, ERNEST, and RANSOME, F. L. Silverton Quadrangle. Geol. Survey Geologic Atlas, Folio 57, 1899.

6. GROSS, WHITMAN, HOWE, ERNEST, and IRVING, J. D. Ouray Quadrangle. Geol. Survey Geologic Atlas, Folio 153, 1907.

7. KELLY, V. C. Geology, Ore Deposits, and Mines of the Mineral Point, Poughkeepsie, and Upper Uncompahgre Districts, Ouray, San Juan, Hinsdale Counties, Colorado. Colorado Sci. Soc., vol. 14, No. 7, 1946.

8. PROSSER, W. C. Tungsten in San Juan County, Colorado. Eng. Min. Jour., vol. 90, 1910, p. 320.

9. PURINGTON, C. W. Telluride Quadrangle. Geol. Survey Geologic Atlas, Folio 57, 1899.

10. VARNES, D. J. Geology and Ore Deposits of the South Silverton Area, San Juan County, Colorado. Pres. at ann. Colorado State Min. Con., Feb. 7, 1948.

Bureau of Mines
Information Circular 7732

HEALTH AND SAFETY ACTIVITIES OF THE BUREAU OF MINES, FISCAL YEAR 1955

BY JAMES WESTFIELD

United States Department of the Interior — January 1956

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* * * * * * * * * Information Circular 7732

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
Thos. H. Miller, Deputy Director

January 1956

HEALTH AND SAFETY ACTIVITIES OF THE BUREAU OF MINES, FISCAL YEAR 1955

by

James Westfield[1/]

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ILLUSTRATIONS

1/ Assistant Director - Health and Safety, Bureau of Mines, Washington, D. C.

Information Circular 7732.

ILLUSTRATION (Con.)

INTRODUCTION

Bureau of Mines activities for safety and health in the mineral industries were reorganized during the fiscal year to provide direct supervision by the Assistant Director - Health and Safety. On December 19, 1954, the field offices conducting these activities were designated as district health and safety offices reporting to the Assistant Director. The functions of determining the causes of accidents and injuries in the mineral industries and recommending measures to eliminate them were continued, with satisfactory results in improved safety records. The inspection of coal mines and enforcement of the Federal Coal Mine Safety Act of 1952 were conducted as directed by the Congress, and safety conditions in the mines were notably improved. One coal-mine explosion classed as a major disaster occurred during the year. The causes of that explosion and means for preventing a recurrence were still under investigation because of the extreme difficulty in recovering several portions of the mine.

Basic research on the nature of certain hazards and ways of eliminating them is continued. Training of individual workmen and supervisors in this knowledge is a major part of the work.

ACKNOWLEDGMENT

The material from which this report was compiled was prepared by the chiefs of the divisions and branches of the health and safety organization.

WORK ON PRIMARY HAZARDS

The two most serious hazards from the standpoint of frequency and severity of injuries to mine workers are roof falls and haulage. Roof falls caused 55 percent of all fatalities in coal mines in 1954, and haulage accidents caused another 23 percent, a total of 78 percent from both. A national campaign to reduce the number killed and injured by falls of rock and coal has been conducted jointly by the Bureau and other national and mineral-industry organizations. Definite results, in reduced numbers of killed and injured, are expected to be shown by the end of 1955. The Bureau has continued its educational program to promote safer practices in controlling roof, haulage, and other operations.

Roof bolting, a method of roof support that the Bureau introduced to the coal-mining industry in 1947, has proved its effectiveness in preventing roof-fall fatalities and continues to gain wide acceptance. During 1954, 120 underground mechanized coal mines used roof bolts exclusively, and 26 percent of the entire production of bituminous-coal mines was mined in roof-bolted areas. Significantly, of the 177 roof-fall fatalities that occurred in bituminous-coal mines during 1954, only 2 resulted from failure of the bolts to support the roof.

In future, the risk of failure of bolted mine roof may be lessened by using a safety device referred to as a roof-bolt compression pad. During fiscal year 1955

the Bureau, seeking to make roof-bolting installations more reliable, developed a rubber-in-steel bearing plate, and a similar device has been produced by industry that appears to be promising as an effective warning device of impending failure of bolted roof.

Recent field and laboratory tests provided the information for determining anchorage effectiveness, torque-tension relationship, and load-carrying capacities of the types of bolts and expansion shells normally used in underground mines. A report embodying the results has been prepared for publication and will be available to the mining industry during fiscal year 1956.

Besides routine roof-control mine examinations, conferences were held during the year with mining-company officials, inspectors of State mining departments, and engineers from various parts of the United States and foreign countries on roof-bolting and roof-control problems. Roof-bolt installations in all districts were surveyed, and reports were submitted to miners' unions, operators, State inspectors, and Bureau headquarters in Washington. Other roof controls studied included extensible canopies, shields on continuous mining machines, curved jacks for longwall continuous mining machines, bonding, and roof painting.

TESTS OF EQUIPMENT

The Bureau's electrical-mechanical test work contributed to improvement of coal-mine safety by: (1) Investigating electrically operated machines and appliances to determine whether they are constituted so as to minimize gas-and-dust ignition hazards as well as electric shock; (2) testing diesel-engine-powered mine locomotives and equipment for safe underground operation (fig. 1); (3) research to determine causes and prevention of accidents to men who work with or around mining equipment; and (4) studying methods for providing better lighting in mines.

During the fiscal year 1955 electrical-mechanical activities included more than 1,600 explosion tests of electrical compartments and enclosures, which led to the formal approval of 73 designs of electrical mining equipment. During the year, 165 approvals were granted, and 2,043 approvals were extended. In addition, 1 electric trip light, 1 flashlight, 1 methane detector, and 4 diesel-powered machines were tested and approved. The mine-lighting study was continued during the fiscal year 1955, and a tentative schedule was prepared for safe lighting equipment for underground illumination in gassy or dusty mines.

To assist the Navy Department in eliminating fire and explosion hazards on aircraft and ships the Bureau investigated, under cooperative agreement with the Navy Department, 12 electrical components and 3 aircraft fuel gages and made 358 explosion tests.

State and Federal laws and regulations require the use of Bureau of Mines-approved equipment in gassy coal mines; therefore, the investigation and testing of electrical mining equipment is a very important activity that will be continued in the fiscal year 1956. Other current activities are studying diesel-powered equipment and testing fire-resistant belts for underground use.

Future electrical-mechanical, long-range activities embrace current investigations and testing, which is of a continuing nature, and new developments in mechanized equipment. It is proposed to investigate the means of reducing gas-ignition and fire hazards from portable cables of electric machinery, which are a major cause of the hazards.

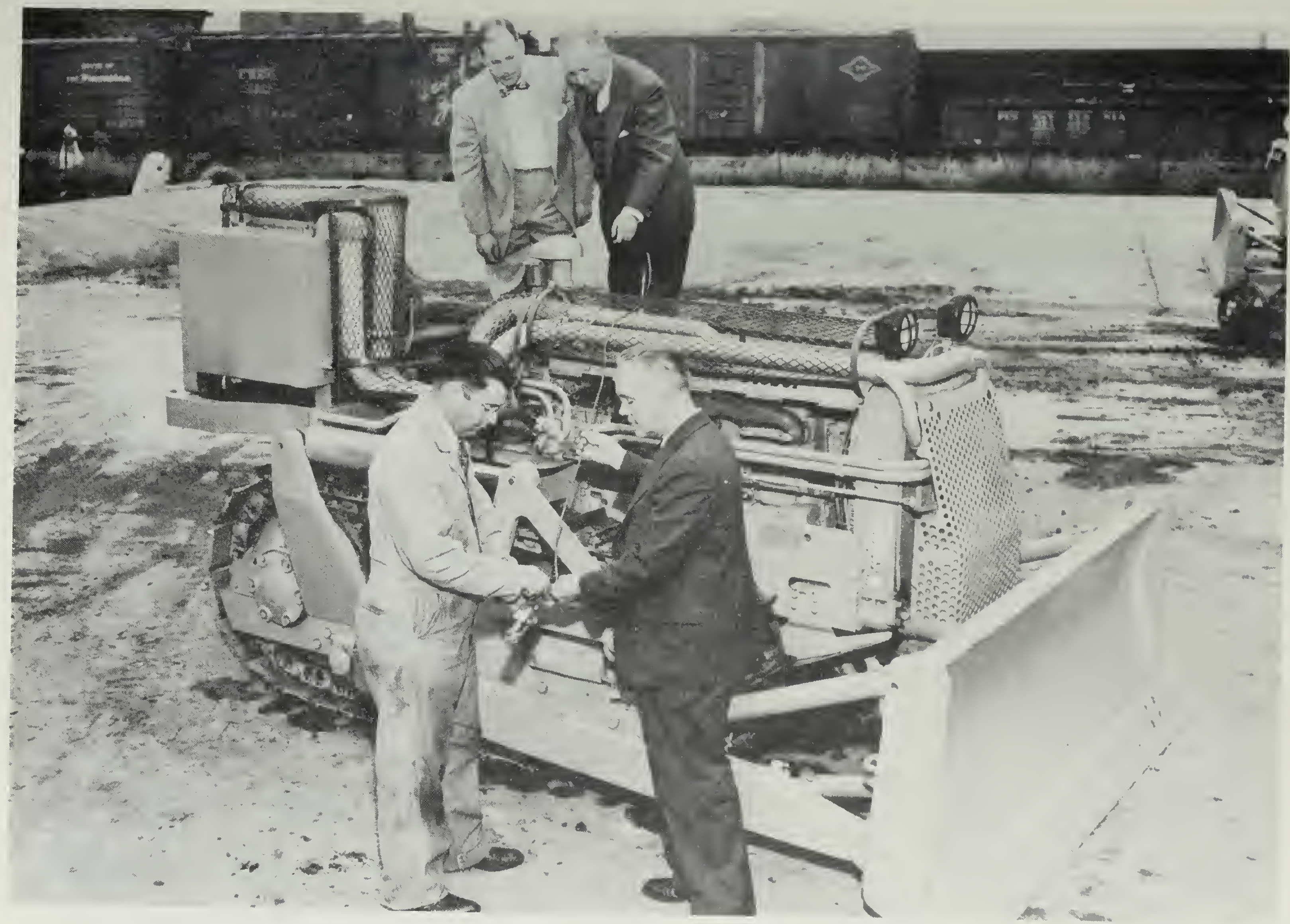

Figure 1. - Bureau of Mines engineers make rigid test on diesel tractor intended for underground use. (Courtesy, J. D. Pittman Tractor Co.)

Seventeen approvals were granted for dust collectors for use in rock drilling in coal mines, and 20 extensions of approval were granted to cover minor modifications in previously approved equipment. (See fig. 2.) A significant development in this field is that four manufacturers were granted approval on drills equipped with hollow drill steel, through which dust and cuttings are drawn and delivered to a filter. A revised schedule (25A) covering approval requirements for drill-dust collectors was issued on April 23, 1955. An experimental coal mine with parallel entries of approximately 270 feet was essentially completed on Government-owned property at Bruceton, Pa. (fig. 3), and will be used for approval testing of drill-dust collectors and other studies relating to mine dust. A high-speed, hydraulic, rotary drill capable of drilling at rates as high as 14 feet per minute was obtained for use in the dust-collector tests.

A total of 59 requests was received for extensions of existing approvals on respiratory protective devices, and 41 extensions of approvals were granted - 32 on gas masks, 2 on supplied-air respirators, 4 on dispersoid respirators, and 3 on nonemergency gas respirators. Requests were received also for approval testing of 6 new gas masks and 1 new type C, supplied-air respirator. Approval BM-1928 was granted on the M. S. A. Dusfoe air-line respirator. Preliminary examinations were made on and consultations held with respirator manufacturers regarding eight respiratory protective devices. Suggestions were made for correcting features considered unsuitable.

Further aging tests of universal-type, gas-mask canisters produced additional evidence that this type of canister attached to timer and face-piece should be stored with the bottom seal intact and that after such canisters have gained 45 grams in weight, owing to absorption of atmospheric moisture, they should be discarded (see fig. 4). Development work was completed on apparatus for testing respirators (fig. 5) against a predetermined and uniform concentration of mists formed while spraying lacquer, enamel, and lead paint. Approval requirements for paint-spray respirators will be based on this work.

HEALTH

General

Activities of the Division of Health were directed to studying and evaluating conditions affecting the quality of the working environment in the mining and allied industries, and to promoting safe and healthful working conditions by providing information on the composition of mine atmospheres (fig. 6), enabling control of undesirable or unsafe conditions caused by gases and dusts; by testing and evaluating equipment for respiratory protection against such atmospheric contaminants; and by studies dealing with improvement of mine ventilation and other conditions relating to the quality of the air in underground workings.

Gas

The continuing study of the composition of mine atmospheres provides the Bureau of Mines with information on this subject accumulated on a nationwide basis. The results obtained in this work are available to State mining departments, to the mining companies concerned, and to miners' unions. In case of mine fires or explosions, gas analyses may be conducted at the scene to expedite rescue or recovery operations. Such an operation was carried out at a West Virginia coal mine after an explosion costly in life and property damage had necessitated sealing the mine to extinguish fires that followed the explosion. Numerous gas analyses made at the

Figure 2. - Approval testing a drill-dust collector in Branch of Health Research Experimental coal mine near Pittsburgh, Pa.

Figure 3. - New Experimental coal mine used by Branch of Health Research for approval testing of drill-dust collectors and for other specialized studies pertaining to dust in mines. Mine is near original Experimental coal mine south of Pittsburgh, Pa.

Figure 4. - Testing gas mask canisters in Bureau laboratory.

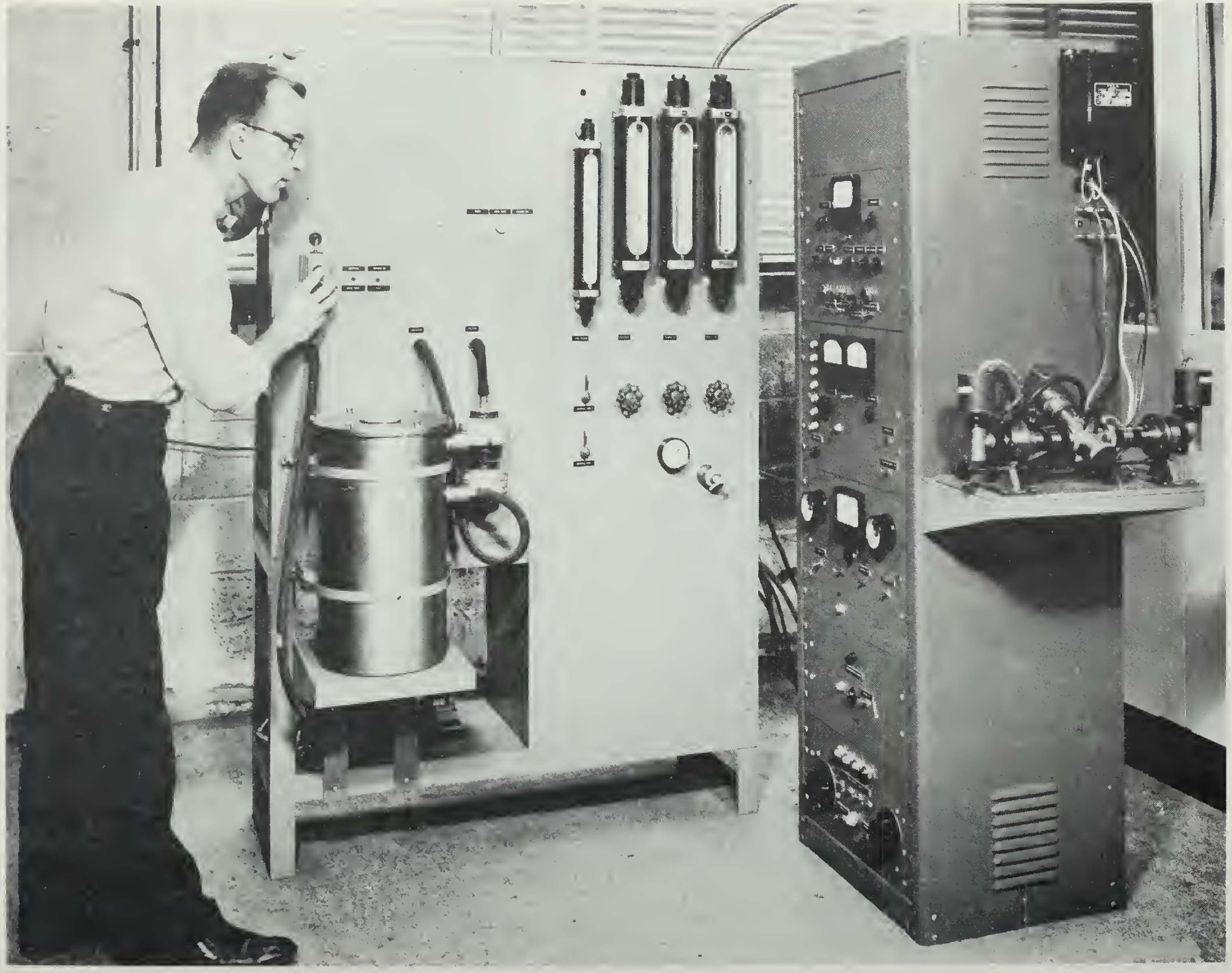

Figure 5. - Apparatus used in approval testing of respirator filters.

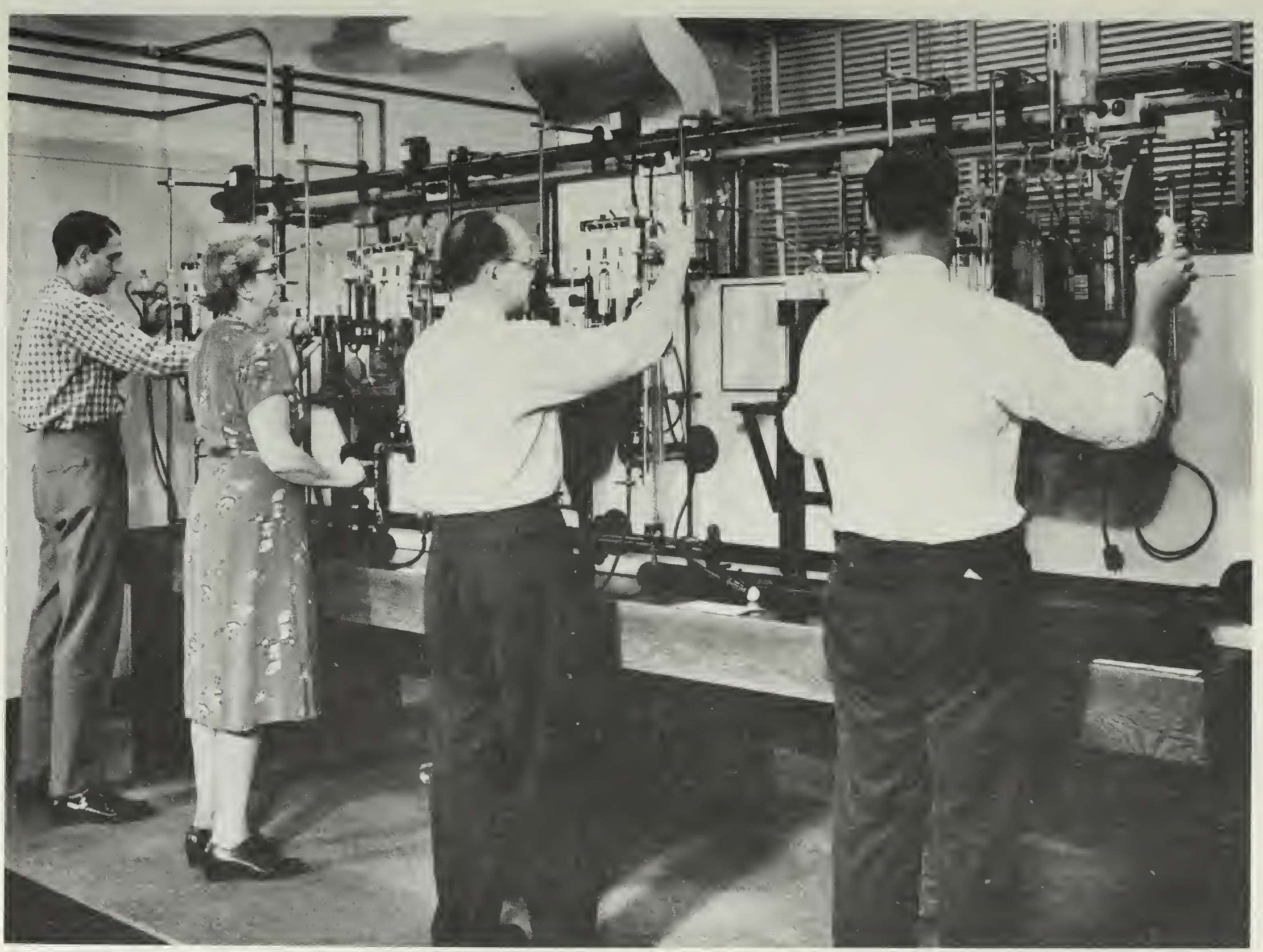

Figure 6. - Bureau of Mines laboratory for analyzing samples of mine atmosphere collected by Federal coal-mine inspectors.

scene to assure the safety of recovery operations greatly facilitated the reopening of the mine.

A total of 18,321 gas samples was analyzed and reported; of these, 16,410 were in connection with the conduct of the Bureau's program of coal-mine inspection. The others were collected from sealed fire areas in coal mines; metal and salt mines; tunnels under construction; coal-preparation plants; and in connection with testing and underground use of diesel and butane engines, plastics and conveyor belt decomposition, and miscellaneous laboratory and field investigations. Over 350 gas samples were analyzed at the scene of operation in sealing and unsealing fire areas in coal mines.

Studies were continued for the Bureau of Ships, Department of the Navy, to determine ignition and burning characteristics and nature and quantity of toxic gases produced by combustion or thermal decomposition of plastic materials for shipboard use and other military applications.

As part of the work of a committee, consisting of Bureau personnel and representatives of conveyor-belt manufacturers, coal operators' associations, the miners' union, and the State of Kentucky, tests were conducted to determine the gaseous products formed by burning or thermal decomposition of rubber-covered conveyor belts and fire-resistant conveyor belts of Neoprene and polyvinylchloride (see fig. 7). The objective of the committee was to formulate specifications for fire-resistant conveyor belts to use in coal mines. A proposed schedule of acceptance requirements was completed.

A double-beam, dispersion-type, recording, infrared spectrometer was obtained primarily to determine both qualitatively and quantitatively the methane content of certain samples of coal-mine atmospheres (fig. 8).

Dust

X-ray diffraction apparatus of the Geiger-tube, goniometer, scanning type was calibrated for determining free silica in dust and other mineral materials (fig. 9) and was employed to analyze 34 samples from a variety of sources. Emission spectroscopy was used to analyze 60 samples from various sources, and work was begun to determine the feasibility of determining silicon by this method as a substitute for chemical determination of total silica in rock dust for coal-mine use.

Counts of dust particles by the light-field microscopic technique were made on 1,183 impinger samples collected in various field and research investigations, and 44 particle-size distribution determinations were completed. Experimental work was done on development of a thermal precipitator dust sampler suitable for use in gassy coal mines. This device would enable dust to be sampled so that electron-microscope examinations of the collected dust could be made directly without redispersion. Studies were made of the sampling efficiency of the midget impinger as related to the velocity of the air sampled. A scale model of two connected mine entries was constructed to determine the behavior and flow pattern of air currents as related to dust transport.

The control of dust produced by the continuous-type mining machine is one of the problems that confronts the coal-mining industry. The effects of various types of spray nozzles as dust suppressors were observed, and arrangements were made to conduct field studies on this problem in several Alabama coal mines.

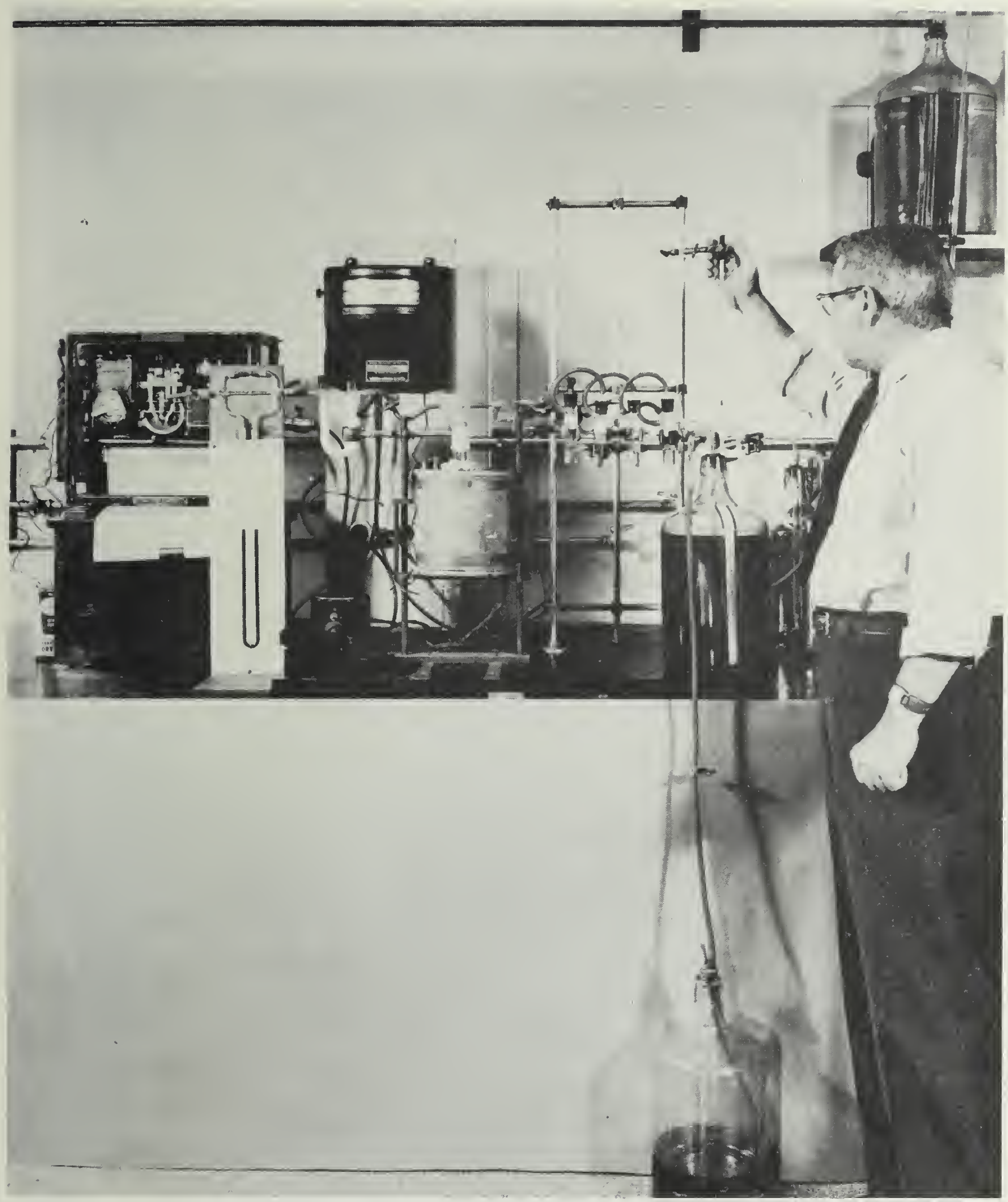

Figure 7. - Apparatus for studying composition of toxic gases from frictional overheating of coal-mine conveyor belts.

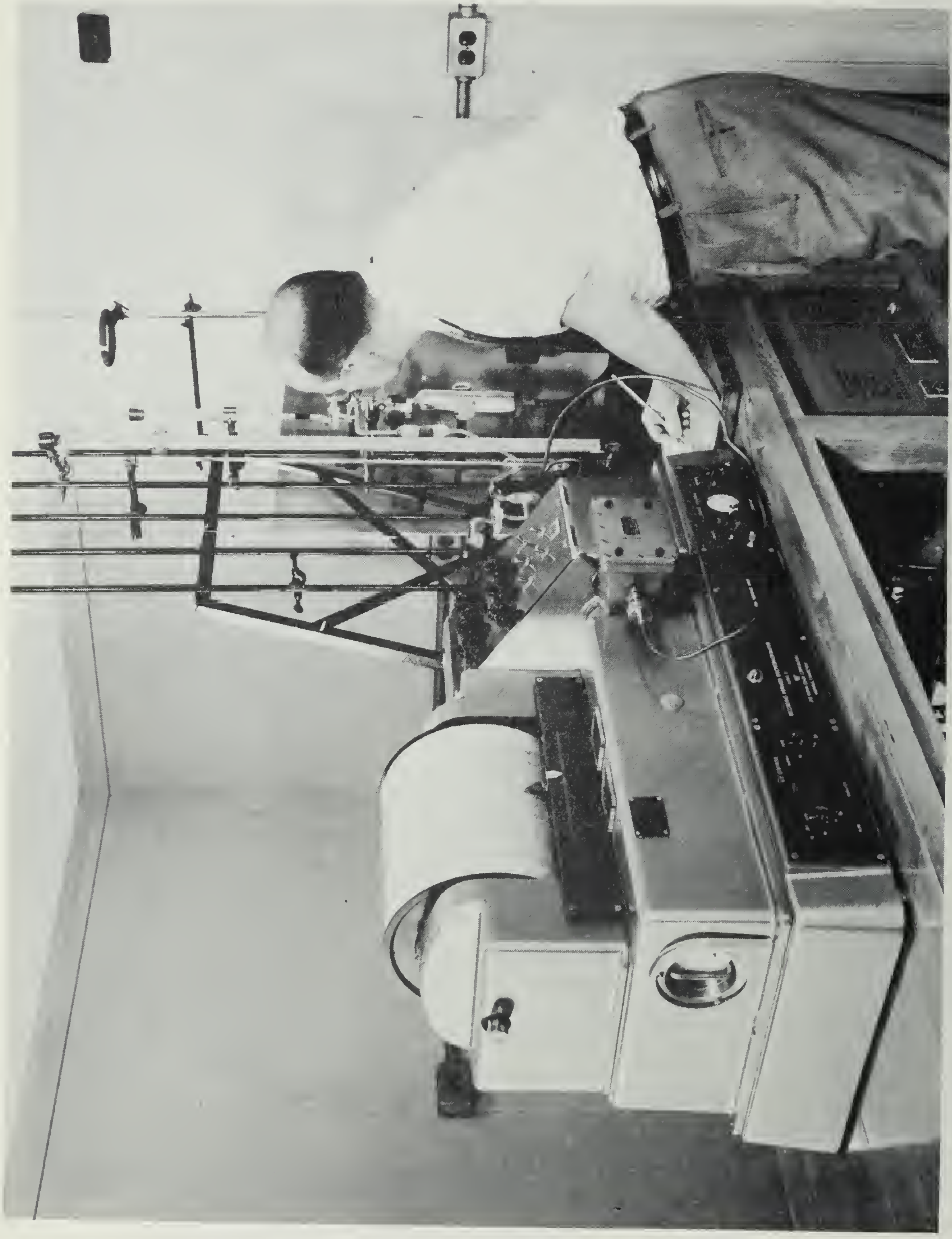

Figure 8. - Infrared absorption spectrometer used primarily for analyzing methane in coal-mine air samples.

Figure 9. - X-ray diffraction apparatus used by Bureau of Mines for determining quartz and other crystalline substances in mine dust, minerals, and other dust-source materials.

A survey of dust-control practices in the coal-mining industry, which was initiated during the preceding year and was conducted through the medium of a questionnaire circulated among Bureau coal-mine inspectors, was completed. The data provided by more than 3,400 replies to the questionnaire were analyzed and the results prepared for publication. The survey showed that about 24 percent of the mines used some form of dust control.

At the request of the International Labor Office, Geneva, Switzerland, an annual summary was prepared reviewing methods of dust prevention and suppression in mining, tunneling, and quarrying.

The major portion of the American Standard Code that deals with respiratory protection was rewritten by personnel serving on A. S. A. Sectional Committee Z2, appointed to correlate and edit material on head, eye, and respiratory protection.

Ventilation

Complete ventilation surveys were made and reports with recommendations were submitted for three coal mines. Records of a study made in February-April 1954 of the effect of barometric pressure changes on methane emission in caved areas in an Illinois coal mine were further analyzed, and a manuscript on this study was submitted for publication. A study of the effectiveness of bleeder entries in keeping caved areas in coal mines free of methane accumulations was begun. The new nonlinear electric analogue for the semiautomatic solution of mine-ventilation-distribution problems and electric-power network analyses was put into full operation for the first time in July 1954 (see fig. 10).

Future Programs

Present functions of the Division of Health will be continued. Future programs for the Branch of Health Research should have objectives of broad scope that would enable collection of information that would be useful on industrywide basis or would be applicable to specific phases of industry. Examples of studies that might be undertaken are: Ventilation of uranium mines and effect of ventilation on concentration of radioactive substances in mine atmospheres; review of air-conditioning practices in deep, hot mines in all countries where such mines are operated; and effect of underground diesel operations on quality of mine atmospheres.

ACCIDENT ANALYSIS

Important among the Bureau's accident-analysis activities are the yearly canvasses for injury and related employment in the coal, coke, quarry, metal, nonmetallic mineral, oil and gas industries. The data collected included the number and types of injuries, cause, accident agency, frequency of occurrence, severity of injury, and certain operating factors closely connected with safety in the mineral industries.

After all data were reviewed and processed through various machine tabulating equipment, publications were prepared for the mineral industries, agencies of the Federal and State governments, labor unions, trade associations, and others interested in promoting safety in the mineral industries.

Special tabulations were prepared for the Federal inspectors showing the safety performance at individual coal mines to improve the effectiveness of their inspections of mines. Data on coal-mine inspection provided information for planning and administrating the Bureau's coal-mine inspection work.

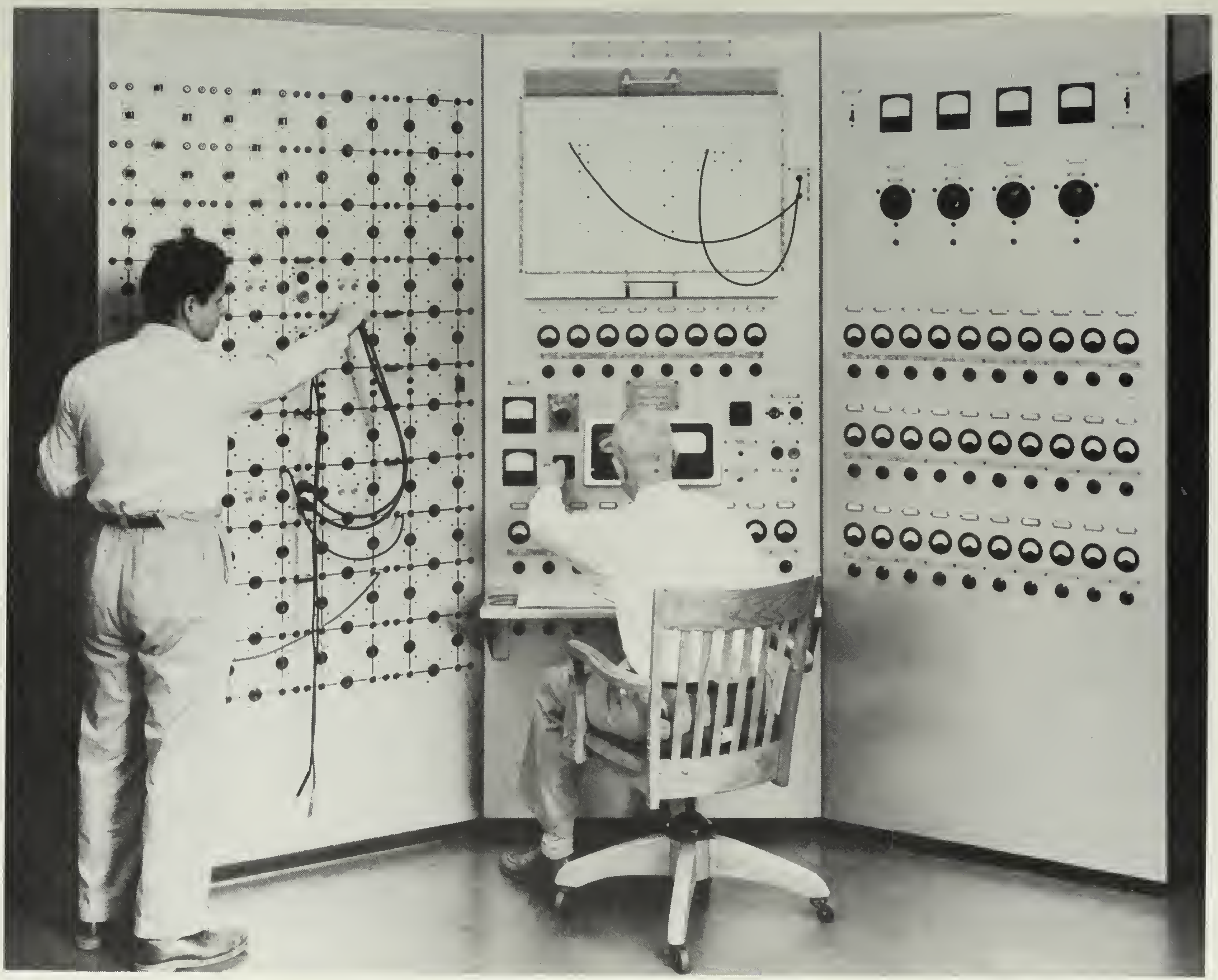

Figure 10. - Bureau of Mines electric analogue for semiautomatic solution of complicated mine-ventilation problems.

The 30th National Safety Competition and four other safety competitions were conducted during the fiscal year 1955. These were sponsored by trade associations of the mineral industries. Approximately 1,500 mines, quarries, and other mineral plants were enrolled in these contests. Approximately 2,000 certificates of Accomplishment in Safety were prepared and presented to the individuals at the plants and to the managers of these plants. The results of these contests were published and distributed widely.

The annual canvass was conducted among the manufacturers of industrial explosives, and a technical report with tabular summaries was prepared and distributed to the makers of the products, libraries, schools, colleges, and other interested persons.

Three chapters were prepared for the 1953 Minerals Yearbook that contained current data pertaining to the injury and related employment experiences in each major group of the mineral industries.

Monthly reports on the fatality experience at coal mines were prepared and released for public information and for use by coal-producing companies, Federal inspectors and engineers, trade and labor groups, and State mining departments. These reports contained data on cause, agency, frequency of fatalities on a man-hour and tonnage basis, and other information pertinent to safety in the coal-mining industry. Monthly reports were also prepared and published showing the nonfatal-injury experience in mining and preparing coal.

During the past fiscal year the Branch of Accident Analyses assumed the responsibility of work previously done by the Statistical Service Branch at College Park. The equipment and personnel were transferred to the Washington office. This move called for changes in personnel and equipment, which were made at substantial monetary savings, and has expedited the finished products of accident analysis. In addition to accident analysis for the Bureau of Mines, the branch did machine statistical work for other divisions of the Bureau and other agencies of the United States Department of the Interior.

Plans for fiscal 1956 include issuing injury data on the mineral industries on a more current basis. Deadline dates have been advanced for completing the collection of statistical data in the field without increasing personnel or equipment.

SAFETY EDUCATION

Leaders of industry have long recognized that one of the best means of reducing accidents and injuries is to educate the workman to recognize hazards and teaching him how to combat them. For years the Bureau has devoted special effort to the coal-mining industry by conducting accident-prevention classes (see fig. 11), because coal mining is one of the most hazardous of the important industries of the Nation. At first, the effort was directed mainly toward training supervisors. Since January 1947 more emphasis has been placed on training the workman, and approximately 125,000 persons have taken the Bureau's 20-hour accident-prevention training course. Although the course is designed primarily for workmen, it has been considered helpful for morale building to have both supervisory officials and workmen take the Bureau's 20-hour course together. In fact, recent emphasis has been placed on 100-percent participation by both workmen and supervisors where the course is presented.

During the fiscal year 1956 it is planned to further emphasize 100-percent training at each facility where an accident-prevention training course is given.

Figure 11. - Federal coal-mine inspector instructing accident-prevention course for workers and supervisors.

Experience has proved that best results in the reduction of accidents and injuries are obtained where every person on the job takes the course. The promotion and enforcement of safety are not limited to management, supervisory officials, or workmen. To obtain best results, united cooperative effort must be exerted. The concept of teamwork must be instilled. The ultimate goal is to make accident-prevention training available to each person who goes underground in the coal-mining industry. Also, during the fiscal year 1956 the Bureau will continue accident-prevention training work for the mining industry other than coal as well as the petroleum and natural-gas industries. Limited personnel and funds have restricted the extent of this work, which has been confined largely to supervisory officials. Bureau training in these fields has been largely first aid.

Since July 1, 1910, approximately 1,850,000 persons throughout the mineral industries have taken the Bureau's first-aid training course, which includes initial training and the refresher course. Approximately 106,000 persons have taken the Bureau's mine rescue course. Approximately 38,000 persons have taken both first aid and mine rescue. The Bureau maintains interest in this fundamental safety work by sponsoring and participating in first-aid contests of a local, State, and national nature. It also sponsors the work of the Holmes Safety Association, a national organization that provides an excellent forum for the discussing accidents and ways to prevent their recurrence. A special effort was made during the year to promote the organization of Holmes Safety Association chapters and councils; 130 such chapters and 6 councils were organized during the year. Holmes Safety Association chapters and councils are an excellent means of promoting safety as they afford an opportunity for men and management to discuss accidents and safety measures.

Future plans for accident-prevention education are to continue and extend present activities. Appropriations will be requested to employ personnel so that the workmen and officials in all the mineral industries will have the opportunity to take a Bureau accident-prevention course designed for each type of mineral industry. It is planned to train every workman and official in the coal-mining industry and to institute retraining. The expenditure of Federal funds will benefit the mineral industries because accidents and injuries are wasteful and costly with respect to losses in manpower, equipment, and property. The continued training in the Bureau's first-aid course will not only be beneficial as a life-saving device in industry, but the persons so trained provide a reservoir of skill that will be of incalculable value if this country is bombed or invaded.

COAL-MINE INSPECTION

The end of fiscal 1955 was the third full year of operation under the Federal Coal Mine Safety Act, which consists of Title I, the original Federal Coal Mine Inspection and Investigation Act of 1941, with slight changes, and Title II, containing certain mandatory provisions designed to prevent explosions, fires, inundations, and man-trip and man-hoist accidents in coal mines employing regularly 15 or more individuals underground.

During fiscal 1955, 3,595 routine inspections were made of coal mines covered under Title II of the act, including 52 made jointly with State inspectors in States that have entered into cooperative agreements with the Bureau under the provisions of the act. In addition, 2,794 special inspections were made to determine the abatement status of violations of Title II that had been cited. Inspectors observed 8,230 violations of the safety provisions of Title II during these inspections, many of which were corrected immediately, thus obviating the need for

issuing formal notices of findings thereon. However, 3,063 original notices setting a reasonable time for abating dangers not corrected promptly, 523 notices granting time extensions, and 3,041 notices certifying that the dangers had been totally abated were issued.

During the year 155 orders requiring the withdrawal of men were issued at 100 mines, 84 orders at 59 mines under the act's imminent danger clause and 71 orders at 41 mines for failure to show good faith in abating violations within a reasonable time. In addition 21 orders were issued classing mines gassy that had hitherto been considered nongassy; however, 5 of these orders were subsequently annulled by the Director or the Federal Coal Mine Safety Board of Review, an independent agency set up by the act following appeals by the operators.

Federal inspectors and engineers also made 6,827 routine inspections of the smaller Title I mines (including 595 inspections of strip mines); 1,012 technical surveys of electrical, ventilation, dust, blasting, and other practices and conditions; and 625 special investigations of fatal and serious nonfatal accidents, mine fires and gas and dust ignitions, and miscellaneous conditions.

During fiscal 1955, 7 applications for annulment of gassy-classification orders issued under Sec. 203(d) of the act were made to the Director; 6 were denied, and 1 was annulled. The Board received three applications for annulment of gassy-classification orders, all appealing adverse decisions by the Director. The Board annulled one order, and the Director has appealed this decision to the United States Court of Appeals - a hearing is pending. Other Board decisions are pending.

The Board also received two applications for annulment of withdrawal orders. One, issued under a State-participation plan, was annulled promptly upon abatement of the violation. The other, appealing an adverse decision by the Director, was annulled following a hearing. This action was appealed by the Director to the Federal Court, which dismissed the case because the appeal was not filed within the 30-day limit.

There were approximately 8,360 active coal mines in the Nation in calendar year 1954, including 1,570 Title II mines, 5,515 small Title I underground mines, and 1,275 strip mines. At the end of the fiscal year 1955, the Division of Coal Mine Inspection had 258 coal-mine inspectors, 45 engineers, 9 coal-mine electrical inspectors, and other supporting personnel variously assigned in coal-mine inspection and safety-education work (fig. 12).

One major coal-mine disaster, a widespread explosion and mine fire that caused the death of 16 men, occurred in the fiscal year 1955. This is the second disaster of major proportions (1 in which 5 or more persons are killed) in 3 years of operation under the antidisaster provisions of Title II of the act. The other was a dust explosion resulting in five deaths in the fiscal year 1953.

Preliminary figures indicate that the number of fatalities in coal mines dropped from 460 in calendar year 1953 to 395 in calendar year 1954, but the frequency rate per million man-hours exposure increased from 0.84 in 1953 to 1.04 in 1954. During the first 6 months of 1955, the preliminary fatality-frequency rate was 1.04. This unfavorable trend is usually experienced during periods of tight markets and marginal operation of coal mines and is influenced by the reduction in man-hours accompanying mechanization.

Figure 12. - Federal coal-mine inspectors undergoing refresher course in mine rescue training at Experimental coal mine.

CONTROL OF FIRES IN INACTIVE COAL DEPOSITS

Since 1949 the Bureau of Mines has engaged in controlling fires in inactive coal deposits on private property and the public domain. Up to fiscal year 1949, when the Congress first made funds available for such purposes, these fires had burned largely unabated. Uncontrolled fires in inactive coal beds have caused the loss of valuable coal reserves, damaged or destroyed surface property, and endangered the lives and health of persons living or working nearby. Many of the fires are in densely populated districts; others are in isolated sections. Some of the fires are in coal outcrops and originate from burning rubbish, brush fires, or camp fires; result from the carelessness of campers or hunters; or are caused by lightning. Other fires occur in abandoned coal-mine openings and may result from creeping outcrop fires or through carelessness or trespassers. Old fires in abandoned mines may break out from sealed areas or new fires may originate from spontaneous combustion.

Of the 196 known fires in inactive coal deposits, 46 have been controlled or are being controlled, 26 of which are on the public domain and 20 on private property. It is estimated that one quarter of a billion tons of coal have been conserved at a cost to the Government of less than 1 cent per ton for fire-control work.

During the fiscal year 1955, 8 fire-control projects were completed; 6 were on the public domain and 2 were on private property. Five additional fire-control projects were in progress at the end of the fiscal year.

Future plans include such maintenance work as may be necessary on completed projects. New fire-control projects will be initiated in the order of urgency and the availability of funds appropriated by Congress for this purpose.

Bureau of Mines
Information Circular 7733

SURVEY OF DUST-CONTROL PRACTICES IN THE COAL-MINING INDUSTRY

By R. W. Barnes, M. J. Gregory, C. W. Owings, and L. B. Berger

United States Department of the Interior — April 1956

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* * * * * * * * * Information Circular 7733

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
Thos. H. Miller, Acting Director

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April 1956

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by

R. W. Barnes,[1] M. J. Gregory,[1] C. W. Owings,[2]
and L. B. Berger[3]

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TABLES (Con.)

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SUMMARY

This circular presents results of a survey conducted by the Bureau of Mines to ascertain the extent to which dust-control practices are employed in the coal-mining industry. This survey was initiated because of increasing realization of the possible harmful effects of the inhalation of dust upon the health of coal-mine workers and the advent, during recent years, of new types of mining machinery and new mining methods that may have a direct effect upon the extent of exposure to airborne dust experienced by persons mining coal.

Anthracite Mines

The survey covered 169 anthracite mines that were operating from November 1, 1953, to July 1, 1954. It showed that large mines employing more than 100 men were doing most to control dust produced during mining.

Control measures were used primarily in drilling, loading, and preparing the coal, and less than half the mines were reported to have been using dust controls on these operations.

Forty-five mines in the anthracite industry employed engineers to study dust hazards and provide means for abating them. Although some controls were used in many mines, much more work remains to be done.

Bituminous-Coal and Lignite Mines

Table 1 summarizes national totals for the primary operations in bituminous-coal and lignite mines - drilling, cutting, loading, and transportation - showing: (1) The number of mines performing an operation of a stated type, and the number and percentage of these mines in which that operation appeared dusty; (2) the number and percentage of mines that used controls to allay dust in a stated operation; and (3) the number and percentage of these mines that appeared dusty.

Review of a few of the most obvious figures presented in table 1 indicates what was being done to control the dust produced in these primary operations.

Drilling

Drilling of the coal face was omitted from table 1(a), as little or nothing was being done to control the dust produced by face drilling, although the coal face was drilled in nearly all mines. Further details are found in the section on drilling (p. 16).

In 15.3 percent of the mines attempts were made to control the dust produced while drilling roof, bottom, or draw slate with rotary drills. Of this number, visible dust was reported in 22.8 percent of the mines. In comparison, 61.9 percent of the mines using percussion drills were equipped with controls, but only 12.0

percent of these were reported dusty. The higher percentage of controls in percussion drilling mines may be attributed to the greater dust production of percussion drilling, and therefore, the more obvious need for control measures.

Table 1(a) shows that very few controls were used in the class A[4/] (Title I) mines and that class C and D mines had the greatest proportion of controls for drilling. Nearly half the mines not using control measures were reported to have visible dust present during the rock drilling. In many instances where dust was not reported as visible, dust may have been present in harmful concentration. Airborne suspensions of rock dust in amounts that are visible to the unaided eye generally are far above the hygienic limit.

These data bring out the need for more control equipment and greater vigilance in using existing equipment if mine workers are to be protected from exposure to potentially harmful dust. A survey of representative mines in the eastern part of the United States showed the average free silica content of mine roof strata to be 27 percent for shales and 55 percent for sandstone.[5 6/] Wet and dry methods of controlling the dust are available, and roof should not be drilled unless adequate control measures are in effect.

Cutting

Coal cutting is one of the dustiest operations involved in coal production. The summary presented in table 1(b) of the national totals again brings out the need for more dust controls and greater operational efficiency of those now in use. Cutting in the bottom of the coal bed usually does not produce as much dust as cutting in other horizons of the bed, but 55 percent of those mines that cut at the bottom and did not use controls were reported to produce visible concentrations of dust. Only 9 percent of the mines that cut in the bottom of the bed used any form of control, and, of those, 49 percent were reported as dusty. A larger proportion of the mines cutting in locations other than the bottom used controls (61 percent), but again these controls appeared far from effective, as 63 percent of these were reported as dusty.

For all types of cutting, those mines using dust control measures made up only 16 percent (derived from data in table 1(b)) of the total. The greater proportion of control measures was used in mines employing over 50 men. Of these mines attempting dust-allaying, only 44 percent were considered successful, on the basis of the observations made.

Loading

Loading coal by machine can produce airborne dust clouds of high concentration. Coal may be loaded in the mine by hand or machine, and in some mines both methods were used. Of the two methods, hand loading produces least dust. Table 1(c) shows that 18 percent of the occurrences of hand loading were dusty and that very few mines (1 percent) attempted to allay dust during hand loading.

4/ Mine classification in respect to number of men employed underground: A = 1 to 14, B = 15 to 49, C = 50 to 99, D = 100 or more.

5/ Westfield, J., Anderson, F. G., Owings, C. W., Harmon, J. P., and Johnson, L., Roof Bolting and Dust Control: Bureau of Mines Inf. Circ. 7615, 1951, 8 pp.

6/ Owings, C. W., and Johnson, L., A Study to Determine Potential Dust Exposure in Connection with Intermittent Rock Drilling in Coal Mines: Bureau of Mines Rept. of Investigations 5004, 1953, 7 pp.

Only 16 percent of the mines loading coal mechanically had any form of dust-control measures on their loading units, and 65 percent of these were reported to have produced no visible dust. Most of the control measures were used in the larger mines.

Efficient use of existing controls and new controls are needed for loading, as for drilling and cutting, to keep the fine material produced in coal mining from becoming airborne and endangering workmen who operate the machines.

Transportation

As shown in table 1(d), mine cars were by far the most common form of transportation. Very little was being done to control the dust they produced, as only 2.4 percent (table 12) of the mines using mine cars were reported to be wetting the coal in transit. Most mines kept their haulage roads clean and prevented dust from being raised by passing trips. Mine-car haulage can present one of the most hazardous dust conditions in coal mining where grades are steep. High silica traction sand used in most mines, when ground to a fine dust and raised into suspension by passing mine cars, may be a hazard for the men exposed to it.

At any point where coal is dumped or transferred from one form of transportation to another considerable dust is likely to be raised. Dust-control measures were generally confined to these points on transportation systems; 20 percent of the shuttle car installations and 27 percent of the conveyor set-ups were equipped with sprays or other means of wetting the coal as it was dumped or discharged into similar or other forms of transportation. Close to half of these controls appeared effective in keeping the dust from becoming airborne, as judged by visual inspection.

TABLE 1. - Summary of dust-control measures used during primary mining operations in bituminous-coal and lignite mines

(a) Drilling other than coal-face

Drill type	Mine class1/	All mines: Number	All mines: Visible dust2/ Number	All mines: Visible dust2/ Percent	Mines using controls: Number	Mines using controls: Percent	Mines using controls: Visible dust2/ Number	Mines using controls: Visible dust2/ Percent
Rotary	A	227	103	45.4	4	1.8	0	0.0
	B	133	55	41.4	7	5.2	1	14.3
	C	75	42	56.0	10	13.3	1	10.0
	D	224	115	51.3	80	37.4	21	26.3
		659	315	47.8	101	15.3	23	22.8
Percussion	A	39	21	53.8	4	10.3	0	0.0
	B	64	38	59.4	21	32.8	4	19.0
	C	89	37	41.6	48	53.9	4	8.3
	D	333	86	25.8	252	75.7	31	12.3
		525	182	34.7	325	61.9	39	12.0

(b) Cutting

Type of cutting	Mine class1/	All mines: Number	All mines: Visible dust2/ Number	All mines: Visible dust2/ Percent	Mines using controls: Number	Mines using controls: Percent	Mines using controls: Visible dust2/ Number	Mines using controls: Visible dust2/ Percent
Bottom	A	932	487	52.3	33	3.5	16	48.5
	B	427	233	54.6	31	7.3	18	58.1
	C	180	120	66.7	25	13.9	15	60.0
	D	287	167	58.2	79	27.5	33	41.8
		1,826	1,007	55.1	168	9.2	82	48.8
Other than bottom	A	26	12	46.2	5	19.2	3	60.0
	B	61	44	72.1	24	39.3	17	70.8
	C	38	29	76.3	24	63.2	17	70.8
	D	165	104	63.0	123	74.5	73	59.3
		290	189	65.2	176	60.7	110	62.5

(c) Loading

Type of loading	Mine class1/	All mines: Number	All mines: Visible dust2/ Number	All mines: Visible dust2/ Percent	Mines using controls: Number	Mines using controls: Percent	Mines using controls: Visible dust2/ Number	Mines using controls: Visible dust2/ Percent
Hand loading	A	2,056	343	16.7	11	0.5	1	9.1
	B	374	74	19.8	3	.8	0	.0
	C	87	25	28.7	4	4.6	0	.0
	D	100	30	30.0	7	7.0	0	.0
		2,617	472	18.0	25	1.0	1	4.0
Mechanical loading	A	120	49	40.8	12	10.0	3	25.0
	B	145	52	35.9	13	9.0	3	23.1
	C	113	53	46.9	16	14.2	7	43.8
	D	281	137	48.8	66	23.5	24	36.4
		659	291	44.2	107	16.2	37	34.6
Hand and mechanical loading	A	8	4	50.0	0	0.0	0	0.0
	B	16	6	37.5	4	25.0	1	25.0
	C	25	13	52.0	2	8.0	1	50.0
	D	76	32	42.1	14	18.4	6	42.9
		125	55	44.0	20	16.0	8	40.0

(d) Transportation

Type of trans-portation	Mine class1/	All mines: Number	All mines: Visible dust2/ Number	All mines: Visible dust2/ Percent	Mines using controls: Number	Mines using controls: Percent	Mines using controls: Visible dust2/ Number	Mines using controls: Visible dust2/ Percent
Mine cars	A	2,115	105	5.0	6	0.3	1	16.6
	B	485	22	4.5	6	1.2	1	16.6
	C	205	16	7.8	11	5.4	1	9.1
	D	432	55	12.7	56	13.0	6	10.7
		3,237	198	6.1	79	2.4	9	11.4
Shuttle cars	A	73	19	26.0	3	4.1	3	100.0
	B	77	22	28.6	10	13.0	4	40.0
	C	92	38	41.3	19	20.7	11	57.9
	D	247	91	36.8	66	26.7	37	56.1
		489	170	34.8	98	20.0	55	56.1
Conveyors	A	132	48	36.4	8	6.1	6	75.0
	B	118	46	39.0	17	14.4	11	64.7
	C	77	36	46.8	24	31.2	12	50.0
	D	174	74	42.5	86	49.4	45	52.3
		501	204	40.7	135	26.9	74	54.8

1/ Mine classes A = 1-14 men underground.
B = 15-49 men underground.
C = 50-99 men underground.
D = 100 or more men underground.

2/ Visible dust: Dust reported on questionnaire as visible to unaided eye.

INTRODUCTION

Background of Survey

Health of miners was one of the primary considerations of the Bureau of Mines when it was organized in 1910. At that time serious conditions existed in some western metal-mining districts. The first director of the Bureau of Mines, Dr. J. A. Holmes, instituted preliminary surveys of dust and ventilation in some of these mines in 1913, assisted by Dr. S. C. Hotchkiss of the United States Public Health Service. These investigations showed that pneumoconiosis was widespread in certain mining districts.

The first investigation of silicosis in the mining industry in the United States was made in 1914-15 by the Bureau of Mines in cooperation with the United States Public Health Service in the Joplin (Mo.) mining district.7/

This study demonstrated definitely the harmful effects of breathing siliceous mine dust, and recommendations were made for relieving such conditions. This field work was continued8 9/ in the following year, including the first detailed X-ray studies of silicosis made in the United States, and the resulting recommendations did much to improve conditions with respect to exposure to airborne dust in the mines and led to the adoption of legislation to help protect the health of mine workers.

In 1916 investigations of "miners' consumption" were begun in the copper mines of the Butte district of Montana.10/ These investigations, lasting for 3-1/2 years, resulted in recommendations, which, when put into effect, directed attention to preventing pneumoconiosis in those areas. Dust and ventilation studies were made in 1919-20 by G. E. McElroy and Dr. R. A. Koronski of the U. S. Public Health Service in the copper-mining district of Arizona, and in the following year similar studies were made by Bureau of Mines engineers and U. S. Public Health Service surgeons in other metal mining districts of the West.

In 1923 dust and ventilation studies were conducted in Alabama ore and coal mines by J. J. Forbes and D. Harrington of the Bureau of Mines and F. V. Meriwether and F. Flinn, surgeons of the U. S. Public Health Service. This study, the first of its kind and extent to be conducted in United States coal mines, demonstrated that coal miners also were subject to pneumoconiosis. Other studies of the effects of exposure to coal-mine dust have developed much additional information.11 12 13/

7/ Lanza, A. J., and Higgins, Edwin, Pulmonary Disease Among Miners of the Joplin District, Missouri, and Its Relation to Rock Dust in the Mines: Bureau of Mines Tech. Paper 105, 1915, 48 pp.

8/ Higgins, Edwin, Lanza, A. J., Laney, F. B., and Rice, G. S., Siliceous Dust in Relation to Pulmonary Disease Among Miners in the Joplin District, Missouri: Bureau of Mines Bull. 132, 1917, 116 pp.

9/ Lanza, A. J., and Childs, S. B., I. Miners' Consumption: A Study of the Disease Among Zinc Miners in Southwestern Missouri. II. Roentgen-Ray Findings in Miners' Consumption: U. S. Public Health Bull. 85, 1917, 40 pp.

10/ Harrington, D., and Lanza, A. J., Miners' Consumption in the Mines of Butte, Mont.: Bureau of Mines Tech. Paper 260, 1921, 19 pp.

11/ Sayers, R. R., Bloomfield, J. J., DallaValle, J. M., Jones, R. R., Dreessen, W. C., Brundage, D. K., and Britten, R. H., Anthraco-Silicosis Among Hard-Coal Miners: U. S. Public Health Bull. 221, 1935, 114 pp.

12/ Flinn, R. H., Seifert, H. E., Brinton, H. P., Jones, J. L., and Franks, R. W., Soft-Coal Miners Health and Working Environment: U. S. Public Health Bull. 270, 1941, 118 pp.

13/ Doyle, H. N., and Noehren, T. H., Pulmonary Fibrosis in Soft-Coal Miners: U. S. Public Health Bibliography Ser. 11, Pub. 352, 1954, 59 pp.

Since 1930 the Bureau of Mines has conducted many investigations dealing with dust conditions in mines and has issued numerous publications describing the hazards of exposure to dust atmospheres and presenting recommendations for controlling them.[14 15 16 17 18 19 20 21 22 23 24] As a result of this work, many mines have adopted the use of dust-controlling devices and dust-allaying systems.

Coal dust is a hazard both from explosion and health standpoints. Dense clouds of dust restrict visibility and cause personal discomfort of men who must work in them. Breathing high concentrations of coal or rock dust contributes to inflammation and infection of the respiratory tract and may eventually lead to pneumoconiosis. Bituminous-coal dust raised into suspension by mining operations is carried by the ventilating current and settles on mine surfaces, increasing the explosion hazard and making it necessary to apply rock dust in such proportion that the mixture will not propagate an explosion if again thrown into suspension in the air. If this coal dust were allayed at the source and prevented from becoming airborne, it is evident that the benefits that could result in the form of safer, more healthful working conditions and a general increase in worker efficiency would more than offset the expense incurred in studying and applying dust-allaying and controlling devices.

Purpose of Survey

To ascertain the extent to which industry controls dust in coal mines, in 1953 the Bureau of Mines conducted a survey by questionnaire to determine the extent to which dust-control practices were being used and how effective they were.

14/ Harrington, D., Dust Hazards and Their Control in Mining: Bureau of Mines Inf. Circ. 6954, 1937, 7 pp.

15/ Littlefield, J. B., Feicht, F. L., and Schrenk, H. H., Bureau of Mines Midget Impinger for Dust Sampling: Bureau of Mines Rept. of Investigations 3360, 1937, 4 pp.

16/ Harrington, D., Forbes, J. J., Cash, F. E., Denny, E. H., Herbert, C. A., Parker, D. J., Owings, C. W., and Miller, A. U., Allaying Dust in Bituminous-Coal Mines With Water: Bureau of Mines Tech. Paper 593, 1939, 55 pp.

17/ Hartmann, I., and Greenwald, H. P., Use of Wetting Agents for Allaying Coal Dust in Mines: Bureau of Mines Inf. Circ. 7131, 1940, 12 pp.

18/ Sayers, R. R., Pulmonary Diseases in the Mining Industry: Bureau of Mines Inf. Circ. 7146, 1941, 26 pp.

19/ Owings, C. W., Some Preliminary Data on Methods for Controlling the Dust Hazards in Mechanical Mining: Bureau of Mines Inf. Circ. 7151, 1941, 12 pp.

20/ Owings, C. W., Methods of Allaying Dust in Underground Mining Operations: Bureau of Mines Rept. of Investigations 3631, 1942, 38 pp.

21/ Kingery, D. S., Some Preliminary Data on Methods for Allaying Coal Dust in Tipples and Cleaning Plants: Bureau of Mines Inf. Circ. 7248, 1943, 11 pp.

22/ Owings, C. W., Suggested Methods for Installing Dust-Allaying Equipment in Bituminous-Coal Mines: Bureau of Mines Rept. of Investigations 3843, 1945, 31 pp.

23/ Johnson, L. H., Dust Problems in the Mines of the Pennsylvania Anthracite Region: Bureau of Mines Tech. Paper 704, 1947, 34 pp.

24/ Westfield, J., Anderson, F. G., Owings, C. W., Harmon, J. P., and Johnson, L., Roof Bolting and Dust Control: Bureau of Mines Inf. Circ. 7615, 1951, 8 pp.

Survey Method

The survey was based upon information gathered especially to analyze dust-control practices. To cover all coal mines in the country in a relatively short time, the Federal coal-mine inspectors were instructed to obtain specific information as they made their regular inspection and to record this information in a special questionnaire (see Appendix E) to be filled out for each mine as it was inspected.

The inspectors were not required to determine or to estimate the concentration of airborne dust in the mines inspected. The only measure made of air dustiness was the observation of whether or not airborne dust was visible, on the assumption that the presence of dust in visible concentration is reasonable evidence that particles of respirable sizes probably are present in excessive amount. Therefore, throughout this report the differentiation of mines or conditions on the basis of visible dust is intended only as a record of an incidental observation rather than an accurate estimation or evaluation of relative air dustiness in respect to possible effects on health. The questionnaire was designed to be answered primarily by check marks or a simple "yes" or "no" to avoid personal opinions as much as possible.

Each mining operation was taken separately; its method of operation and any methods for controlling the dust produced were recorded. In general, the answers obtained seemed to give a clear picture of the operation when the inspection was made.

Discussion of Questionnaire

As the results obtained by circulating any type of questionnaire can be no better than the form or manner in which the questions are asked, the functioning of this questionnaire was analyzed as replies were received.

A few weak points were detected in the questionnaire that should be corrected if future surveys are conducted. A question under drilling was whether water had been applied during drilling to control the dust. This was misunderstood in a number of instances to mean that the drilling was or was not being done in a wet place.

No correlation was asked for between the amount of roof drilling and the number of roof bolts installed; therefore, the proportion of roof drilling done for roof bolting could not be determined.

Under Coal Cutting the exact method of cutting the coal face could not be determined. A large mine might use all the cut-locations shown in the questionnaire and in different combinations in different parts of the mine. If all the locations were checked there was no way to establish what combination of cut-positions was used and what control measures were used on each.

A question in the next section, Blasting, asked if the place was wetted before blasting. This was taken to mean, variously, that the place was naturally wet, that it was wetted during cutting, or that it was deliberately wetted immediately before blasting.

Under Transportation and Loading a question asked if loaded material was wetted before or during loading or transportation: If the answer to this were yes, there was no way of deciding whether it was meant to mean before the operation, during the operation, or both.

In general, the questionnaire did not ask for enough detail or provide enough space for information on dust-control equipment in use, so that the relative effectiveness of the types could be compared.

The questionnaire did not mention the high-silica sand dust on haulage roads, and no information regarding the exposure of workmen to this hazard was obtained. However, this rather controversial subject probably would be best resolved by extensive sampling of actual mine atmospheres rather than by observation or opinion.

A few inspectors apparently took the entire questionnaire to be based upon a desire to obtain information on dust in respect to the explosion hazard rather than to the health standpoint for which it was intended.

On the last page of the questionnaire a space was provided for additional remarks about any unusual dust-control methods observed. Almost no information was obtained in this space. Presumably, either every mine uses standard dust-allaying and controlling devices, or this section was overlooked because of its location in the questionnaire.

All things being considered, the questionnaire form used gathered a large quantity of valuable information even though a few points of interest were missed.

Number of Mines Surveyed

The survey covered 3,413 bituminous-coal and lignite mines and 169 anthracite mines, representing all mines that were operating from November 1, 1953, to July 1, 1954, except for a few small "wagon" mines operated too sporadically to be inspected during this period.

ACKNOWLEDGMENTS

Circulation of the questionnaire used to obtain the information presented in this report was authorized by J. J. Forbes, Director, and James Westfield, Assistant Director - Health and Safety, of the Bureau of Mines. The data of the survey were collected by the Federal coal-mine inspectors of the Division of Coal-Mine Inspection. These men were selected because they provided the most practicable means by which the coal mines in the United States could be covered in a reasonably short period. The authors wish to express their sincere appreciation for the interest and cooperation of all concerned and particularly for the work done by the coal-mine inspectors, which was additional to their regular duties.

EXPLANATION OF TABLES

The tables presented for the anthracite mines contain the data on dust control for drilling, blasting, loading, and transportation. Information on other operations is presented in the text. These tables show the use and relative effectiveness of dust controls and the number of and dust conditions of mines where controls were not used.

The States in which the bituminous-coal and lignite mines are situated are arranged in decreasing order of daily coal production. West Virginia is the leading producer and has been divided into Northern West Virginia and Southern West Virginia. Northern West Virginia includes all the northern part of the State and extends south to the Kanawha field on the west and to the Webster-Gauley field on the east. Southern West Virginia includes these two fields and all the area of the State south of them. The State was divided in this manner because the characteristics of the

coal beds in the two areas vary widely, and the equipment and mining practices vary with the beds. Another outstanding difference between the two areas is the size of the mines. Few small mines are operated in the southern part of the State, but in the northern section they are abundant.

Arkansas, Oklahoma, Washington, and Wyoming are grouped together in Group I, and Iowa, Maryland, Missouri, Montana, and New Mexico are assembled in Group II. The data from these States are combined because all are relatively small coal producers and individual mines might be identifiable in some of the tables. Georgia, Kansas, and North Dakota had 9 active mines with a total employment of 101 men. Since these States used no control measures, they were excluded from the tables.

The mines have been classified according to size in each State. The Federal Coal-Mine Safety Act divides coal mines into two size groups; Title I includes all mines in which not more than 14 men are employed underground, and Title II includes mines that employ 15 or more men underground. In assembling the data, it was found that Title II mines divided readily into three groups. In the tables, each size group has been assigned a letter, as follows:

Class of mine	Men employed underground	
A	1-14	Title I
B	15-49	Title II
C	50-99	Title II
D	100 or more	Title II

The first part of each table shows the State-by-State data for the operation being reported for the mines in each employment class. The second part of each table shows the national totals for each phase of the operation being reported for each employment class. The table also shows the number and percentage of mines in each category in which visible dust was reported. In some instances an operation was reported as being done in more than one way in the same mine; therefore, the number of operations or occurrences of an operation do not always equal the total number of mines covered by the survey.

Each table is accompanied by an explanation of the main points of the table and a discussion of the factors involved in the amount and control of dust produced by the operation under consideration.

DUST CONTROL IN THE ANTHRACITE INDUSTRY

The mines and mining systems in the anthracite industry differ widely from those in the bituminous-coal-producing areas. The steeply pitching coal measures, the faulting of the strata, and the character of the coal make it impossible to apply many systems used in bituminous mining. The coal tonnage produced per man employed underground is lower in most anthracite mines than in comparable bituminous-coal mines because of difficult mining conditions in the anthracite field.

These anthracite mines produced 94,492 tons of coal daily. A total of 169 mines was operating at the time of this survey, employing 27,739 men underground.

Generally, the anthracite industry is extremely dust conscious and has done much to control dust produced in mining operations. Because of the systems of mining, much work is done in solid rock, and the pneumoconiosis hazard is greater than for work done primarily in coal. Pneumoconiosis has been contracted in the past by men working in the anthracite mines.[25/] The number of disabled miners has

25/ See work cited in footnote 11, p. 5.

been steadily decreasing, but dust-control work remains to be done, as this survey shows. More and better systems of dust control are needed, and the use of existing systems and devices must be made more efficient if the hazard of pneumoconiosis is to be eliminated.

Face Drilling

Nearly every available method was used to drill the coal face throughout the anthracite mines, but rotary drilling without dust control made up about 60 percent of the face drilling. Of those occurrences, 37 percent were reported dusty. Only 8 of 115 mines used controls on rotary face drilling, and these controls were effective in all but 1 mine.

Percussion drilling of the face was practiced to a lesser extent than rotary drilling, and again controls generally were not used; 16 percent of the percussion drills were equipped with controls. Water was the most effective control medium, as no dust was reported in any of the 10 instances where it was used. About 60 percent of the dust collectors were not effective, as 3 out of 5 were reported to allow escape of visible dust.

Rock Drilling

The dust produced by drilling rock is far more hazardous to breathe than that produced by drilling coal because of its high silica content. Most rock drilling (75 percent) was done by percussion machines. The most widely used method of controlling the dust produced by these drills was to apply water, which appeared effective in all but one instance. Only 13.6 percent of the percussion drill set-ups were equipped with dust collectors, and 70 percent of these were reported to allow escape of visible dust; 50 percent of the percussion drilling occurrences had no controls, and of these 76.5 percent were reported to produce visible dust.

In rock, rotary drilling was practiced to a lesser extent than percussion drilling. Very few controls were in use on these machines; only 13 percent were equipped with collectors or used water. In the mines that did not use controls for rotary drilling about half were found to produce visible dust.

It must be borne in mind that these data were based on the coal-mine inspectors' visual observations, and that a lack of visible dust does not necessarily mean that no dust was present. Harmful concentrations of airborne mineral dusts may be present but invisible to the unaided eye. The term "visible dust" may represent a rather extreme case.

It is evident that many installations of both rotary and percussion drills in the anthracite mines needed some form of dust control.

Cutting

Little cutting is done in the anthracite mines, as frequently the coal beds are steeply pitching, and cutting machines cannot be used. Only eight of the mines investigated (all Class D) cut coal, and each of these used bottom-cutting machines. Controls to allay the dust were employed in 4 of these, and only 2 were reported to produce no visible dust. The mines that did not cut the coal blasted it from the solid face.

Blasting

Most anthracite mines used permissible explosives, but a few used dynamite in rock headings.

All blasting was done by State-certified miners, and the larger part of the blasting was done on shift, but a few mines in each size class shot at the end of the shift or off-shift.

Many (40 percent) of the Class D mines wetted the coal after it was blasted to help allay the dust produced when this coal was loaded. A few of the smaller mines (Classes A, B, and C) wetted the coal before blasting, after blasting, or both.

Thirteen class D mines were reported to have dust and smoke present when men returned after blasting; five class B and C mines also were reported to have this condition. However, ventilation was good in most mines, and in the instances mentioned the men probably returned to the places too quickly.

Loading

Hand loading was practiced extensively in both small and large mines. Mechanical-loading units were used only where seam conditions permitted. Relatively little visible dust was reported to be produced during loading in class A, B, or C mines. The greatest number of dusty operations was found in the class D mines that loaded the coal by both hand and mechanical means. The absence of visible dust in the class A, B, and C mines probably was a result of the natural wetness of many of the mines and the application of water to the coal both before and during loading in the others. Most of the control measures used during loading were reported in class D mines. (See figs. 1 and 2.)

Transportation

Mine cars and conveyors were found to be essentially the only form of transportation used in the anthracite mines. One mine used shuttle cars, and, although there was no dust control, dust was not reported.

About one-fourth of the mine cars used in class D mines were dusttight. In the other 3 classes of mines 15 percent of the mine cars used were dusttight. Few cars were found to be overloaded, and only two mines were reported to have atmospheric dust visible on haulageways. Most haulage roads were kept clean and many were naturally wet, which kept most of the dust out of the air. The coal was wetted in transit in 10 mines.

Sixty-six conveyor installations were in use, but only three mines used any form of dust control in conjunction with them. Only 8 occurrences of visible dust were reported, 1 of which was an installation where controls were used.

Ventilation

All mines except three used mechanical ventilation. The air was carried to the face in the majority of these mines, and in the remainder ventilation was carried at least to the last crosscut. In general, ventilation was good for all classes of mines.

Figure 1. - Loading coal into car from conveyor without using water.

Figure 2. - Loading coal into car from conveyor using water to allay the dust (same working place as in fig. 1).

Tipples and Cleaning Plants

Over half the class D mines were reported to use dust-control measures on tipples or cleaning plants. A few of the other mines used dust-control measures. Of 12 installations in class A, B, and C mines, only 3 were reported to need more controls or have controls that were not effective. Of the class D mines using controls, 36 percent were considered by the inspectors to need more controls or more effective application of those in use.

Some of the smaller mines did not use controls, but the only point at which dust was reported was at the dump. Other small mines and some large mines that did not use controls had no visible dust, so it is assumed that the coal was too wet to produce dust.

Dust-Control Engineers

The anthracite industry employs more men to study dust conditions and dust-control practices than the bituminous industry. A total of 45 mines in 12 different companies were reported as having dust-control engineers or men that did this work. All these mines were reported to conduct dust surveys.

TABLE 2. - Use and relative effectiveness of dust-control practices in anthracite mines, by mine class, during drilling (face, roof, bottom, and draw slate)

Type of drilling	Mines		Dry-drilling occurrences						Wet-drilling occurrences		
			No controls			Dust collector					
				Visible dust			Visible dust			Visible dust	
	Class[1/]	Number	Number	Number	Percent	Number	Number	Percent	Number	Number	Percent
Rotary	A	31	30	5	16.6	1	0	0	0	0	0
	B	50	45	12	26.7	-	-	-	1	0	0
	C	21	19	5	26.3	-	-	-	-	-	-
	D	67	58	38	65.5	4	1	25.0	9	2	22.2
		169	152	60	39.5	5	1	20.0	10	2	20.0
Percussion	A	31	12	7	58.3	2	2	100.0	1	0	0
	B	50	33	16	48.5	4	3	75.0	6	0	0
	C	21	13	7	53.8	1	1	100.0	2	0	0
	D	67	90	70	77.8	8	4	50.0	59	1	1.7
		169	148	100	67.6	15	10	66.7	68	1	1.5
Rotary and percussive drilling		169	300	160	53.3	20	11	55.0	78	3	3.8

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.

TABLE 3. - Extent of applying water before and after blasting in anthracite mines, by mine class

Mines		Wetted							
		After blasting		Before blasting		Before and after blasting		Naturally wet	
Class1/	Number	Number	Percent	Number	Percent	Number	Percent	Number	Percent
A	31	1	3.2	0	0	0	0	0	0
B	50	2	4.0	1	2.0	2	4.0	2	4.0
C	21	2	9.5	0	0	2	9.5	1	4.8
D	67	27	40.3	0	0	6	9.0	0	0
	169	32	18.9	1	0.6	10	5.9	3	1.8

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.

TABLE 4. - Use and relative effectiveness of dust-control measures during loading in anthracite mines, by mine class and loading practice

Type of loading	Mines		Controls used			No controls used		
				Visible dust			Visible dust	
	Class1/	Number	Number	Number	Percent	Number	Number	Percent
Hand	A	31	-	-	-	22	0	0
	B	50	1	0	0	20	5	25.0
	C	21	2	0	0	8	1	12.5
	D	67	2	0	0	16	6	37.5
		169	5	0	0	66	12	18.2
Mechanical	A	31	-	-	-	1	0	0
	B	50	-	-	-	7	1	14.3
	C	21	-	-	-	1	0	0
	D	67	2	0	0	8	0	0
		169	2	0	0	17	1	5.9
Hand and mechanical	A	31	-	-	-	8	0	0
	B	50	2	1	50.0	20	4	20.0
	C	21	-	-	-	10	0	0
	D	67	13	3	23.1	26	12	46.2
		169	15	4	26.7	64	16	25.0
All loading		169	22	4	18.2	147	29	19.7

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.

TABLE 5. - Extent of dust-control practices in relation to mine cars, coal in transit, and main-line haulage roads in anthracite mines, by mine class

Mines		Tight cars, number mines	Overloaded cars, number mines	Wetted cars, number mines	Naturally wet haulageways	Cleaned haulageways	Wetted haulageways
Class1/	Number						
A	31	4	0	1	5	28	0
B	50	9	1	2	18	38	0
C	21	3	0	1	10	13	1
D	67	15	6	6	23	55	2
Totals	169	31	7	10	56	134	3

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.

DUST CONTROL IN THE BITUMINOUS-COAL AND LIGNITE INDUSTRY

Drilling

The Federal Mine Safety Code of 1953 for underground bituminous-coal and lignite mines states in Article IX, Section lb, "The dust from drilling rock shall be controlled by the use of permissible dust collectors or by water or water with a wetting agent."

It has long been recognized that exposing workmen to siliceous airborne dust produced by rock drilling may be harmful. This exposure, however, may be greatly reduced if precautions are taken to collect or otherwise control this dust before it becomes airborne and is breathed by the workmen. From the data in table 6 it may be concluded that this was not being done in the majority of mines.

Drilling is done in United States coal mines for blasting or roof bolting. The equipment used for drilling falls into two main classes; percussion and rotary. Percussion drills are operated pneumatically and generally are of the stoper or jackhammer types. Rotary drills generally are driven by electric or hydraulic motors. In some small mines hand-powered augers still are used; these are turned at such a slow speed that little dust is produced.

Pneumatic percussion drilling is a very dusty operation if there is no means of collecting or controlling the dust. The chief methods of dust control are water and dust collectors. Water is introduced through the drill steel and wets most of the cuttings as they are formed. Dust collectors can catch much of the dust and cuttings and prevent them from being disseminated into the air.

Rotary drilling need not be as dusty as percussion drilling. Hydraulically operated and controlled drills can be regulated to give high bit pressure and slower rotational speed, thus producing a high rate of penetration and less fine dust. Hand-held hydraulic drills and electric units do not have this advantage and may produce considerable dust. Dust collectors may be used for rotary drills in the same manner as for percussion drills, but if water is used during rotary drilling, it usually is sprayed on the cuttings as they emerge from the hole. Water used in percussion drilling usually controls the dust well, but on rotary units the fine dust is already in suspension and a water spray around the collar of the hole serves only to suppress the larger particles. Water is also introduced through the steel as in percussion drilling. A Bureau of Mines approved dust collector can keep the dust concentration in the breathing zone of the driller below 10 million particles per cubic foot of air if the device is properly maintained and is used in the manner for which approval was granted.

Face Drilling

Drilling the coal face preparatory to placing explosives or other coal-breaking devices throws little dust into suspension in small mines where hand augers are used; but, where high-speed electric or hydraulic drills are used, high concentrations of dust can be produced. Factors affecting the production of dust are: The drill speed, the height of the hole above the bottom, the sharpness and type of the drill bit, and the moisture content of the coal. Those mines that did not drill in the face either did all the work by hand or employed one of the continuous-type mining machines requiring no blasting.

TABLE 6. - Use and relative effectiveness of dust-control measures d

State	Mines: Class mines 1/	Mines: Number	Draw-slate drilling, Rotary drilling, No controls: Number	No controls: Visible dust	Dry with collector: Number	Dry with collector: Visible dust	Wet: Number	Wet: Visible dust	Total: Number	Total: Visible dust	Perc, No controls: Number	No controls: Visible dust	Dry col: Number
West Virginia (Northern)	A	171	-	-	-	-	-	-	-	-	-	-	-
	B	79	3	1	-	-	-	-	3	1	-	-	-
	C	18	-	-	-	-	-	-	-	-	-	-	-
	D	27	2	2	-	-	-	-	2	2	-	-	-
West Virginia (Southern)	A	39	-	-	-	-	-	-	-	-	-	-	-
	B	76	3	0	-	-	1	0	4	0	1	0	1
	C	61	2	2	-	-	1	0	3	2	2	1	2
	D	148	9	2	2	1	-	-	11	3	3	1	7
Pennsylvania	A	280	5	2	-	-	-	-	5	2	1	1	-
	B	103	4	1	-	-	-	-	4	1	1	1	-
	C	31	3	1	-	-	-	-	3	1	-	-	-
	D	95	9	5	12	5	4	0	25	10	4	3	2
Kentucky	A	416	5	1	-	-	-	-	5	1	-	-	-
	B	114	13	3	-	-	-	-	13	3	-	-	-
	C	49	5	4	1	0	-	-	6	4	2	2	1
	D	62	5	3	1	1	-	-	6	4	-	-	1
Illinois	A	15	2	1	-	-	-	-	2	1	-	-	-
	B	11	-	-	-	-	-	-	-	-	-	-	-
	C	4	1	1	-	-	-	-	1	1	-	-	-
	D	30	4	3	-	-	-	-	4	3	-	-	-
Virginia	A	298	-	-	-	-	-	-	-	-	1	1	-
	B	44	1	0	-	-	-	-	1	0	4	4	-
	C	12	1	1	-	-	-	-	1	1	1	1	1
	D	22	1	0	-	-	-	-	1	0	-	-	-
Alabama	A	178	1	0	-	-	-	-	1	0	1	0	-
	B	14	-	-	-	-	-	-	-	-	-	-	-
	C	8	2	0	-	-	-	-	2	0	-	-	-
	D	18	-	-	-	-	-	-	-	-	-	-	2
Ohio	A	166	1	0	-	-	-	-	1	0	-	-	-
	B	27	1	0	1	0	-	-	2	0	-	-	-
	C	4	-	-	-	-	-	-	-	-	-	-	-
	D	16	7	5	1	0	-	-	8	5	-	-	-
Tennessee	A	307	2	0	-	-	-	-	2	0	-	-	-
	B	15	-	-	-	-	-	-	-	-	-	-	-
	C	13	1	1	-	-	-	-	1	1	-	-	-
	D	17	-	-	-	-	-	-	-	-	-	-	-
Utah	A	20	-	-	-	-	-	-	-	-	-	-	-
	B	4	-	-	-	-	-	-	-	-	-	-	-
	C	7	-	-	-	-	-	-	-	-	-	-	-
	D	7	-	-	-	-	-	-	-	-	-	-	-
Indiana	A	13	-	-	-	-	-	-	-	-	-	-	-
	B	14	-	-	-	-	-	-	-	-	-	-	-
	C	2	-	-	-	-	-	-	-	-	-	-	-
	D	8	-	-	-	-	-	-	-	-	-	-	-
Colorado	A	103	-	-	-	-	-	-	-	-	-	-	-
	B	17	-	-	-	-	-	-	-	-	-	-	-
	C	6	-	-	-	-	-	-	-	-	-	-	-
	D	4	-	-	-	-	-	-	-	-	-	-	-
Group I2/	A	26	-	-	-	-	-	-	-	-	-	-	-
	B	12	-	-	-	-	-	-	-	-	-	-	-
	C	9	-	-	-	-	-	-	-	-	-	-	-
	D	8	-	-	-	-	-	-	-	-	-	-	-
Group II3/	A	153	3	3	-	-	-	-	3	3	-	-	-
	B	20	1	1	-	-	-	-	1	1	-	-	-
	C	2	1	1	-	-	-	-	1	1	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-
Total		3,413	98	44	18	7	6	0	122	51	21	15	17
Percent with reported dust			44.9		38.9		0.0		41.8		71.4		0

See footnotes at end of table.

TABLE 6. - Use and relative effectiveness of dust-control measures during drilling in bituminous-coal and lignite mines. A: By States and mine class

State	Mines		Face drilling										Roof drilling															
			Rotary drilling				Percussion dry no control		Total mines power drilling		Hand drilling	No drilling	Rotary drilling								Percussion drilling							
			No controls		Controls								No controls		Dry with collector		Wet		Total		No controls		Dry with collector		Wet		Total	
	Class mines 1/	Number	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust			Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust
West Virginia (Northern)	A	171	94	6	-	-	-	-	94	6	74	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	B	79	62	14	-	-	-	-	62	14	17	-	3	3	-	-	-	-	3	3	6	6	4	2	-	-	10	8
	C	18	14	4	-	-	-	-	14	4	4	-	-	-	-	-	-	-	-	-	2	2	4	1	-	-	6	3
	D	27	25	10	1	0	-	-	26	10	1	-	-	-	3	0	9	5	12	5	-	-	10	4	2	2	12	6
West Virginia (Southern)	A	39	36	7	-	-	-	-	36	7	3	-	1	0	-	-	-	-	1	0	-	-	-	-	-	-	-	-
	B	76	68	9	-	-	1	0	69	9	7	-	3	3	1	1	-	-	4	4	4	2	4	0	1	0	9	2
	C	61	59	19	-	-	-	-	59	19	2	-	6	3	2	1	-	-	8	4	4	3	6	1	5	0	15	4
	D	148	143	33	-	-	1	0	144	33	4	-	17	13	7	1	3	0	27	14	9	7	38	6	36	1	83	14
Pennsylvania	A	280	234	47	1	0	-	-	235	47	42	3	13	9	-	-	-	-	13	9	4	4	-	-	-	-	4	4
	B	103	80	20	-	-	-	-	80	20	21	2	12	7	-	-	-	-	12	7	4	2	-	-	-	-	4	2
	C	31	28	12	-	-	-	-	28	12	3	-	7	3	3	0	-	-	10	3	3	2	1	0	-	-	4	2
	D	95	89	41	2	1	-	-	91	42	3	1	11	10	9	0	1	0	21	10	12	10	27	2	6	1	45	13
Kentucky	A	416	403	133	-	-	-	-	403	133	12	1	45	31	-	-	-	-	45	31	4	3	-	-	-	-	4	3
	B	114	113	38	-	-	-	-	113	38	1	-	29	11	2	0	-	-	31	11	3	3	1	0	1	0	5	3
	C	49	47	18	-	-	1	1	48	19	-	1	8	7	1	0	-	-	9	7	10	10	2	0	-	-	12	10
	D	62	60	21	1	0	-	-	61	21	1	-	16	10	5	3	5	0	26	13	8	6	11	3	8	1	27	10
Illinois	A	15	15	10	-	-	-	-	15	10	-	-	4	3	-	-	-	-	4	3	-	-	-	-	-	-	-	-
	B	11	10	10	-	-	-	-	10	10	1	-	2	2	-	-	-	-	2	2	-	-	-	-	-	-	-	-
	C	4	4	4	-	-	-	-	4	4	-	-	3	3	-	-	-	-	3	3	-	-	-	-	-	-	-	-
	D	30	29	25	-	-	-	-	29	25	-	1	17	16	1	0	1	1	19	17	2	2	-	-	-	-	2	2
Virginia	A	298	289	14	-	-	-	-	289	14	9	-	8	1	-	-	-	-	8	1	4	3	-	-	-	-	4	3
	B	44	42	4	-	-	-	-	42	4	2	-	6	3	1	0	-	-	7	3	6	5	-	-	-	-	6	5
	C	12	11	4	-	-	-	-	11	4	1	-	2	2	1	0	-	-	3	2	2	2	2	0	-	-	4	2
	D	22	22	2	-	-	-	-	22	2	-	-	5	2	4	2	1	0	10	4	2	2	4	1	1	0	7	3
Alabama	A	178	165	24	-	-	-	-	165	24	12	1	33	21	0	-	-	-	33	21	6	4	-	-	-	-	6	4
	B	14	12	3	-	-	-	-	12	3	1	1	3	1	0	-	-	-	3	1	2	1	-	-	1	0	3	1
	C	8	8	3	-	-	-	-	8	3	-	-	2	1	0	-	-	-	2	1	2	1	-	-	2	0	4	1
	D	18	18	5	-	-	-	-	18	5	-	-	2	1	1	0	-	-	3	1	1	1	7	0	4	0	12	1
Ohio	A	166	155	82	-	-	-	-	155	82	11	-	3	1	-	-	-	-	3	1	-	-	-	-	-	-	-	-
	B	27	21	10	1	0	-	-	22	10	5	-	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-
	C	4	3	2	-	-	-	-	3	2	-	1	2	0	-	-	-	-	2	0	-	-	-	-	-	-	-	-
	D	16	14	7	1	0	-	-	15	7	-	1	-	-	4	0	-	-	4	0	-	-	-	-	1	0	1	0
Tennessee	A	307	76	5	-	-	1	1	77	6	228	2	10	3	-	-	-	-	10	3	4	0	-	-	-	-	4	0
	B	15	7	3	-	-	1	1	8	4	7	-	2	0	-	-	-	-	2	0	1	1	-	-	1	0	2	1
	C	13	12	4	-	-	1	1	13	5	-	-	4	4	-	-	-	-	4	4	4	3	-	-	2	1	6	4
	D	17	13	5	-	-	-	-	13	5	4	-	3	3	1	1	-	-	4	4	6	4	2	1	-	-	8	5
Utah	A	20	19	12	-	-	-	-	19	12	1	-	1	1	-	-	-	-	1	1	-	-	-	-	1	0	1	0
	B	4	4	3	-	-	-	-	4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C	7	7	5	-	-	-	-	7	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	0	6	0
	D	7	7	3	-	-	-	-	7	3	-	-	-	-	-	-	-	-	-	-	-	-	1	0	5	1	6	1
Indiana	A	13	12	4	-	-	1	1	13	5	-	-	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-
	B	4	4	2	-	-	-	-	4	2	-	-	1	0	-	-	-	-	1	0	-	-	-	-	-	-	-	-
	C	2	2	2	-	-	-	-	2	2	-	-	1	1	-	-	-	-	1	1	-	-	1	1	-	-	1	1
	D	8	8	7	-	-	-	-	8	7	-	-	4	4	2	1	-	-	6	5	2	2	2	0	-	-	4	2
Colorado	A	103	79	38	-	-	-	-	79	38	9	15	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-
	B	17	17	13	-	-	-	-	17	13	-	-	-	-	1	0	-	-	1	0	1	1	-	-	-	-	1	1
	C	6	6	5	-	-	-	-	6	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	0
	D	4	4	2	-	-	-	-	4	2	-	-	1	0	-	-	-	-	1	0	-	-	1	0	-	-	1	0
Group I 2/	A	26	15	4	-	-	-	-	15	4	10	1	5	4	-	-	-	-	5	4	1	1	-	-	-	-	1	1
	B	12	10	2	-	-	-	-	10	2	1	1	3	2	-	-	-	-	3	2	2	2	-	-	1	0	3	2
	C	9	8	2	-	-	-	-	8	2	1	-	2	0	-	-	-	-	2	0	-	-	-	-	1	0	1	0
	D	8	7	3	-	-	-	-	7	3	1	-	3	3	-	-	-	-	3	3	1	1	-	-	-	-	1	1
Group II 3/	A	153	68	15	-	-	2	1	70	15	60	23	14	5	-	-	-	-	14	5	1	1	1	0	-	-	2	1
	B	20	10	4	-	-	-	-	10	4	2	8	3	2	-	-	-	-	3	2	-	-	-	-	-	-	-	-
	C	2	2	1	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total		3,413	2,770	785	7	1	9	6	2,786	792	561	66	323	202	49	10	20	6	392	218	123	97	129	22	86	7	338	126
Percent with reported dust				28.3		14.3		66.7		28.4				62.5		20.4		30.0		55.6		78.9		17.1		8.1		37.3

See footnotes at end of table.

TABLE 6. - Use and relative effectiveness of dust-control measures during drilling in bituminous-coal and lignite mines. A: By States and mine class (Con.)

State	Mines		Draw-slate drilling																Bottom drilling															
			Rotary drilling								Percussion drilling								Rotary drilling								Percussion drilling							
			No controls		Dry with collector		Wet		Total		No controls		Dry with collector		Wet		Total		No controls		Dry with collector		Wet		Total		No controls		Dry with collector		Wet		Total	
	Class mines 1/	Number	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust
West Virginia (Northern)	A	171	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	B	79	3	1	-	-	-	-	3	1	-	-	-	-	-	-	-	-	1	0	-	-	-	-	1	0	-	-	-	-	-	-	-	-
	C	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	27	2	2	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
West Virginia (Southern)	A	39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-
	B	76	3	0	-	-	1	0	4	0	1	0	1	0	-	-	2	0	1	0	-	-	-	-	1	0	2	1	-	-	-	-	2	1
	C	61	2	2	-	-	1	0	3	2	2	1	2	0	-	-	4	1	-	-	-	-	-	-	-	-	3	2	2	0	1	0	6	2
	D	148	9	2	2	1	-	-	11	3	3	1	7	0	12	0	22	1	1	0	-	-	2	0	3	0	10	4	4	1	20	0	34	5
Pennsylvania	A	280	5	2	-	-	-	-	5	2	1	1	-	-	-	-	1	1	19	0	-	-	3	0	22	0	1	0	-	-	-	-	1	0
	B	103	4	1	-	-	-	-	4	1	1	1	-	-	-	-	1	1	16	6	-	-	-	-	16	6	3	2	-	-	-	-	3	2
	C	31	3	1	-	-	-	-	3	1	-	-	-	-	-	-	-	-	4	3	1	0	-	-	5	3	2	2	-	-	-	-	2	2
	D	95	9	5	12	5	4	0	25	10	4	3	2	0	1	0	7	3	7	2	1	0	-	-	8	2	10	5	9	3	6	2	25	10
Kentucky	A	416	5	1	-	-	-	-	5	1	-	-	-	-	-	-	-	-	16	9	-	-	-	-	16	9	1	1	-	-	-	-	1	1
	B	114	13	3	-	-	-	-	13	3	-	-	-	-	-	-	-	-	4	2	-	-	-	-	4	2	-	-	-	-	1	0	1	0
	C	49	5	4	1	0	-	-	6	4	2	2	1	0	-	-	3	2	4	2	-	-	-	-	4	2	2	0	-	-	-	-	2	0
	D	62	5	3	1	1	-	-	6	4	-	-	1	0	3	0	4	0	5	1	-	-	-	-	5	1	4	1	1	0	3	0	8	1
Illinois	A	15	2	1	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	B	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C	4	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	30	4	3	-	-	-	-	4	3	-	-	-	-	-	-	-	-	9	6	-	-	-	-	9	6	1	1	-	-	-	-	1	1
Virginia	A	298	-	-	-	-	-	-	-	-	1	1	-	-	-	-	1	1	2	0	-	-	-	-	2	0	1	0	-	-	-	-	1	0
	B	44	1	0	-	-	-	-	1	0	4	4	-	-	-	-	4	4	1	0	-	-	-	-	1	0	·1	1	2	2	-	-	3	3
	C	12	1	1	-	-	-	-	1	1	1	1	1	0	-	-	2	1	1	1	-	-	-	-	1	1	1	1	1	0	-	-	2	1
	D	22	1	0	-	-	-	-	1	0	-	-	-	-	-	-	-	-	1	0	-	-	-	-	1	0	-	-	1	1	2	1	3	2
Alabama	A	178	1	0	-	-	-	-	1	0	1	0	-	-	-	-	1	0	12	1	-	-	1	0	13	1	4	1	-	-	1	0	5	1
	B	14	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	0	-	-	-	-	-	-	-	-	1	1	-	-	-	-	1	1
	C	8	2	0	-	-	-	-	2	0	-	-	-	-	-	-	0	0	1	0	-	-	-	-	1	0	-	-	-	-	-	-	-	-
	D	18	-	-	-	-	-	-	-	-	-	-	2	0	-	-	2	0	2	1	-	-	-	-	2	1	1	1	1	0	1	0	3	1
Ohio	A	166	1	0	-	-	-	-	1	0	-	-	-	-	-	-	-	-	3	1	-	-	-	-	3	1	-	-	-	-	-	-	-	-
	B	27	1	0	1	0	-	-	2	0	-	-	-	-	-	-	-	-	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-
	C	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0	-	-	-	-	2	0	-	-	-	-	-	-	-	-
	D	16	7	5	1	0	-	-	8	5	-	-	-	-	-	-	-	-	1	0	-	-	-	-	1	0	-	-	-	-	-	-	-	-
Tennessee	A	307	2	0	-	-	-	-	2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	B	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C	13	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	-	-	-	-	1	0
Utah	A	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	0
	B	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C	7	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	0	-	-	-	-	-	-	-	-	-	-	-	-	3	0	3	0
	D	7	-	-	-	-	-	-	-	-	-	-	-	-	4	0	4	0	-	-	-	-	-	-	-	-	-	-	-	-	4	0	4	0
Indiana	A	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	B	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	-	-	-	-	1	0	-	-	-	-	-	-	-	-
	C	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	1	0	-	-	5	4
Colorado	A	103	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	-	-	-	-	3	1	1	1	-	-	-	-	1	1
	B	17	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	0	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-
	C	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-
Group I 2/	A	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	2	1	-	-	-	-	-	-	-	-
	B	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	1	0	2	1
	C	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	3	0	4	1
	D	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	1	1	-	-	-	-	1	0	1	0
Group II 3/	A	153	3	3	-	-	-	-	3	3	-	-	-	-	-	-	-	-	8	2	-	-	-	-	8	2	-	-	-	-	-	-	-	-
	B	20	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-	6	3	-	-	-	-	6	3	-	-	-	-	-	-	-	-
	C	2	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total		3,413	98	44	18	7	6	0	122	51	21	15	17	0	23	0	61	15	137	46	2	0	6	0	145	46	56	31	22	7	48	3	126	41
Percent with reported dust			44.9		38.9		0.0		41.8		71.4		0.0		0.0		24.6		33.6		0.0		0.0		31.7		55.4		31.8		6.3		32.5	

See footnotes at end of table.

uring drilling in bituminous-coal and lignite mines. A: By States and mine class (Con.)

cussion drilling					Bottom drilling															
					Rotary drilling								Percussion drilling							
with lector	Wet		Total		No controls		Dry with collector		Wet		Total		No controls		Dry with collector		Wet		Total	
Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	1	0	-	-	-	-	1	0	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-
0	-	-	2	0	1	0	-	-	-	-	1	0	2	1	-	-	-	-	2	1
0	-	-	4	1	-	-	-	-	-	-	-	-	3	2	2	0	1	0	6	2
0	12	0	22	1	1	0	-	-	2	0	3	0	10	4	4	1	20	0	34	5
-	-	-	1	1	19	0	-	-	3	0	22	0	1	0	-	-	-	-	1	0
-	-	-	1	1	16	6	-	-	-	-	16	6	3	2	-	-	-	-	3	2
-	-	-	-	-	4	3	1	0	-	-	5	3	2	2	-	-	-	-	2	2
0	1	0	7	3	7	2	1	0	-	-	8	2	10	5	9	3	6	2	25	10
-	-	-	-	-	16	9	-	-	-	-	16	9	1	1	-	-	-	-	1	1
-	-	-	-	-	4	2	-	-	-	-	4	2	-	-	-	-	1	0	1	0
0	-	-	3	2	4	2	-	-	-	-	4	2	2	0	-	-	-	-	2	0
0	3	0	4	0	5	1	-	-	-	-	5	1	4	1	1	0	3	0	8	1
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	9	6	-	-	-	-	9	6	1	1	-	-	-	-	1	1
-	-	-	1	1	2	0	-	-	-	-	2	0	1	0	-	-	-	-	1	0
-	-	-	4	4	1	0	-	-	-	-	1	0	1	1	2	2	-	-	3	3
0	-	-	2	1	1	1	-	-	-	-	1	1	1	1	1	0	-	-	2	1
-	-	-	-	-	1	0	-	-	-	-	1	0	-	-	1	1	2	1	3	2
-	-	-	1	0	12	1	-	-	1	0	13	1	4	1	-	-	1	0	5	1
-	1	0	1	0	-	-	-	-	-	-	-	-	1	1	-	-	-	-	1	1
-	-	-	0	0	1	0	-	-	-	-	1	0	-	-	-	-	-	-	-	-
0	-	-	2	0	2	1	-	-	-	-	2	1	1	1	1	0	1	0	3	1
-	-	-	-	-	3	1	-	-	-	-	3	1	-	-	-	-	-	-	-	-
-	-	-	-	-	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-
-	-	-	-	-	2	0	-	-	-	-	2	0	-	-	-	-	-	-	-	-
-	-	-	-	-	1	0	-	-	-	-	1	0	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	-	-	-	-	1	0
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1	0
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	1	0	1	0	-	-	-	-	-	-	-	-	-	-	-	-	3	0	3	0
-	4	0	4	0	-	-	-	-	-	-	-	-	-	-	-	-	4	0	4	0
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	1	0	-	-	-	-	1	0	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	1	0	-	-	5	4
-	-	-	-	-	3	1	-	-	-	-	3	1	1	1	-	-	-	-	1	1
-	1	0	1	0	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-
-	-	-	-	-	2	1	-	-	-	-	2	1	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	1	0	2	1
-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	3	0	4	1
-	-	-	-	-	1	1	-	-	-	-	1	1	-	-	-	-	1	0	1	0
-	-	-	-	-	8	2	-	-	-	-	8	2	-	-	-	-	-	-	-	-
-	-	-	-	-	6	3	-	-	-	-	6	3	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0	23	0	61	15	137	46	2	0	6	0	145	46	56	31	22	7	48	3	126	41
.0	0.0		24.6		33.6		0.0		0.0		31.7		55.4		31.8		6.3		32.5	

TABLE 6. - Use and relative effectiveness of dust-control measures during drilling in bituminous-coal and lignite mines. B: Breakdown of national totals by mine size

Location	Drilling method	Class A[1]			Class B[1]			Class C[1]			Class D[1]		
		Number	Visible dust	Percent	Number	Visible dust	Percent	Number	Visible dust	Percent	Number	Visible dust	Percent
Face drilling	Rotary, no control.....	1,660	401	24.2	460	135	29.3	211	85	40.3	439	164	37.4
	Rotary with control....	1	-	-	-	-	-	-	-	-	5	1	20.0
	Percussion, no control.	4	3	75.0	2	1	50.0	2	2	100.0	1	-	-
Roof drilling	Rotary, no control.....	139	81	58.3	68	35	51.5	37	24	64.9	79	62	78.5
	Rotary dry, dust collector.............	-	-	-	5	1	20.0	7	1	14.3	37	8	21.6
	Rotary wet.............	-	-	-	-	-	-	-	-	-	20	6	30.0
	Percussion, no controls	24	16	66.7	29	23	79.3	27	23	85.2	43	35	81.4
	Percussion dry, dust collector	1	-	-	9	2	22.2	16	3	18.8	103	17	16.5
	Percussion wet	1	-	-	5	-	-	17	1	5.9	63	6	9.5
Draw slate drilling	Rotary, no control	19	7	36.8	26	6	23.1	16	11	68.8	37	20	54.1
	Rotary dry, dust collector	-	-	-	1	-	-	1	-	-	16	7	43.8
	Rotary wet	-	-	-	1	-	-	1	-	-	4	-	-
	Percussion, no controls	3	2	66.7	6	5	83.3	5	4	80.0	7	4	57.1
	Percussion dry, dust collector	-	-	-	1	-	-	4	-	-	12	-	-
	Percussion wet	-	-	-	2	-	-	1	-	-	20	-	-
Bottom drilling	Rotary, no control	65	15	23.1	32	13	40.6	12	6	50.0	28	12	57.7
	Rotary dry, dust collector	-	-	-	-	-	-	1	-	-	1	-	-
	Rotary wet	4	-	-	-	-	-	-	-	-	2	-	-
	Percussion, no controls	8	3	37.5	8	6	75.0	9	6	66.7	31	16	51.6
	Percussion dry, dust collector	-	-	-	2	2	100.0	3	-	-	17	5	29.4
	Percussion wet	2	-	-	2	-	-	7	-	-	37	3	8.1

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.
2/ Group I consists of Wyoming, Oklahoma, Washington, and Arkansas, listed in order of production.
3/ Group II consists of Iowa, Montana, New Mexico, Missouri, and Maryland, listed in order of production.

Only 7 of the 2,786 mines that drilled in the coal face with power drills were reported to use any form of dust-control measures. One of the seven was reported as producing visible dust while drilling. Nine mines drilled the coal face with percussion drills, and none used dust-control measures.

The 561 mines that drilled with hand augers were mostly small mines (Title I) employing less than 15 men.

Roof Drilling

Generally, more rotary than percussion drills were used for drilling roof rock, except in West Virginia where percussion drills were in the majority. The relative effectiveness of the control methods and their proportionate use is shown for roof drilling in figure 3(a) and (b). As stated before, water was not as effective for allaying the dust from rotary drills as it was for dust produced by percussion drills. This is evident from the data presented in table 6. The greatest use of dust collectors and wet drilling was in the class D (100 or more men) mines, and virtually no controls were used in the very small mines.

In spite of the hazard from dust produced by drilling roof, only 39 percent of the mines that drilled roof used any form of dust control. In nearly half the mines that drilled roof, visible dust was reported during drilling whether or not controls were used. Of the mines in which dust controls were used, 81 percent appeared by observation to be controlling the dust effectively.

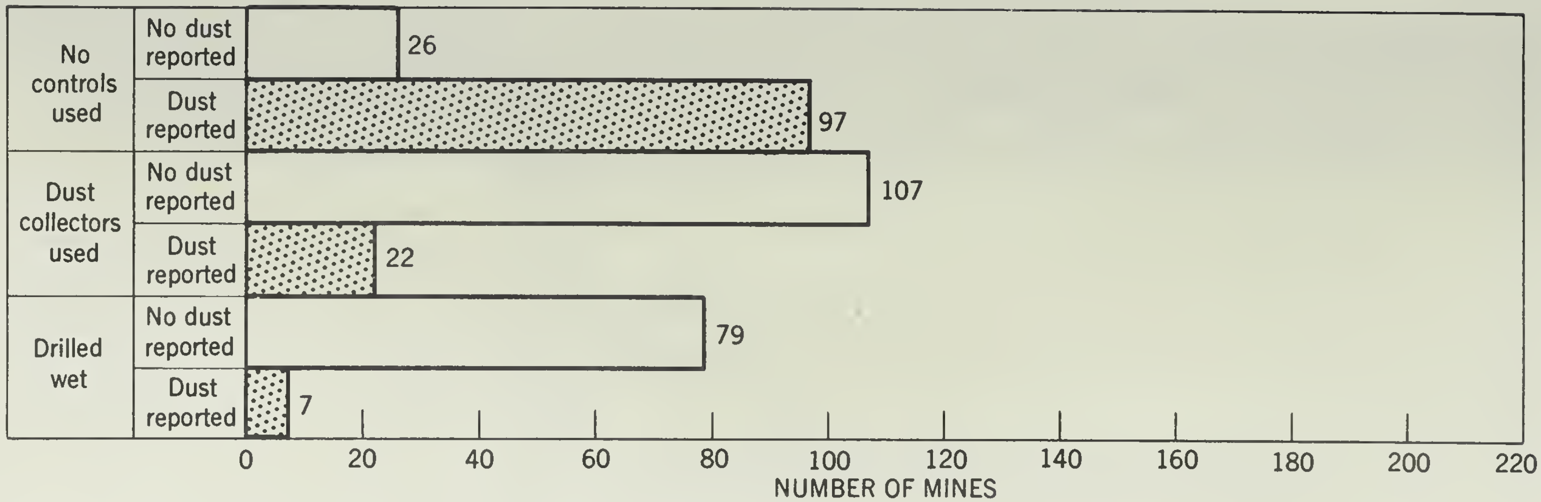
Draw-Slate Drilling

Most draw-slate drilling was practiced in West Virginia, Pennsylvania, and Ohio, where the Pittsburgh coal bed is predominant, and in Kentucky, where the coal beds generally are low. In the Pittsburgh coal bed the draw slate generally is removed for safety reasons, while in Kentucky it is taken down for additional working height.

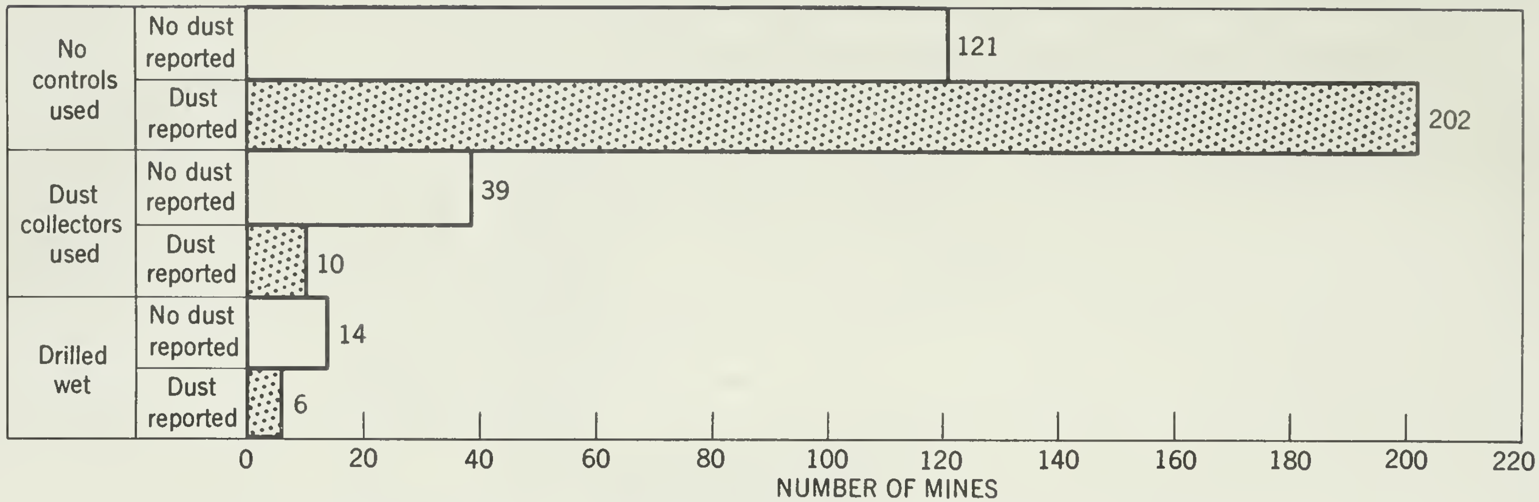
The use and relative effectiveness of the control measures used for draw-slate drilling are shown graphically in figure 4(a) and (b). It can be seen from these figures that the control methods do a better job on percussion drills than on rotary drills. By comparing the graphs for percussion and rotary drilling, it is evident also that more controls were used for percussion drills than for rotary drills, even though nearly twice as many rotary units were in use. Draw-slate generally is drilled with horizontal holes, and the cuttings produced fall only from the collar of the hole to the floor and are not thrown into suspension to the extent that results with vertical drilling. These horizontal holes usually are drilled with the same drills used for the coal face, which generally are slower than those intended for roof drilling. These factors tend to explain the fact that so many mines were observed in which draw slate was drilled without controls, yet without producing visible dust.

Bottom Drilling

Rotary drills were found in more general use than the percussion type for bottom drilling. The use and relative effectiveness of the two types of drills are shown graphically in figure 5(a) and (b). Water is a more effective dust control for downward drilling than for drilling in other directions, as the dust does not fall free from the hole and in that manner become suspended. Dust collectors were not as successful in controlling the dust from down holes as they were from others.

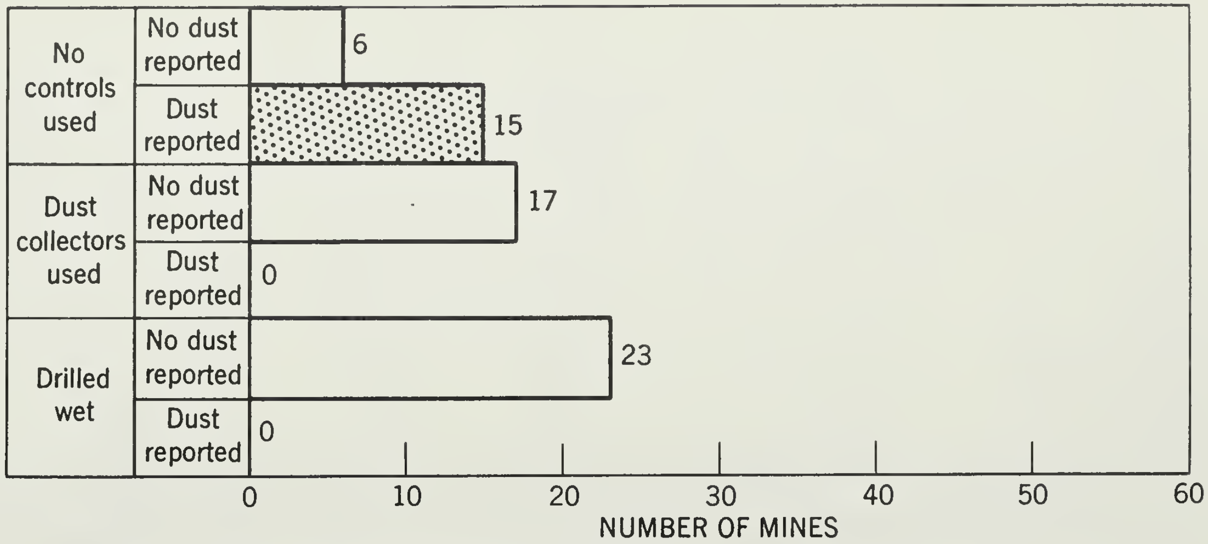


The use and relative effectiveness of dust controls used during percussion drilling in 338 mines.

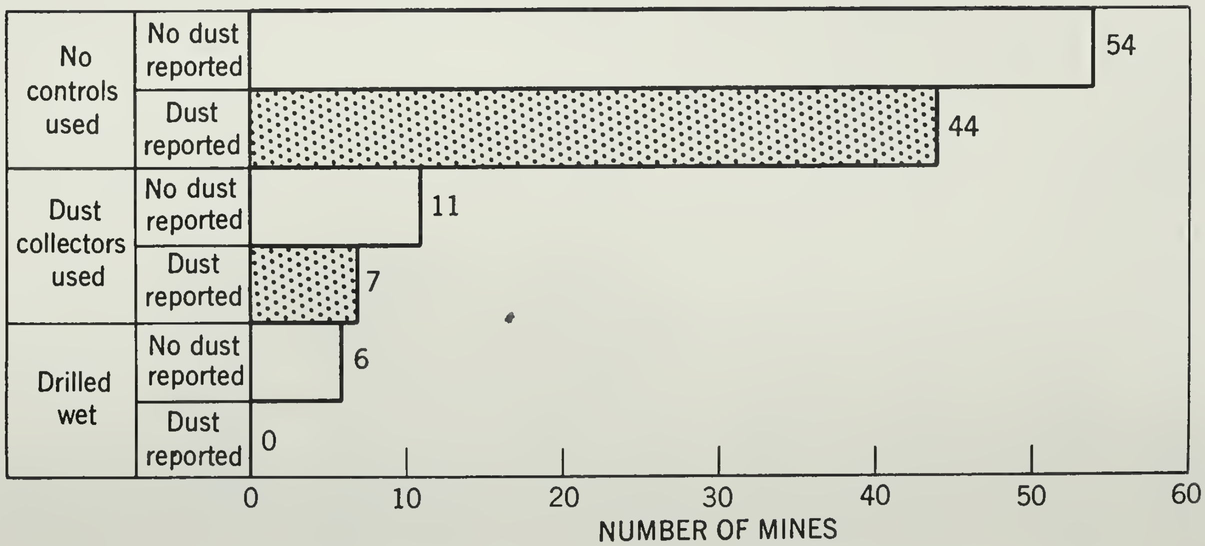


The use and relative effectiveness of dust controls used during rotary drilling in 392 mines.

Figure 3. - Roof drilling.

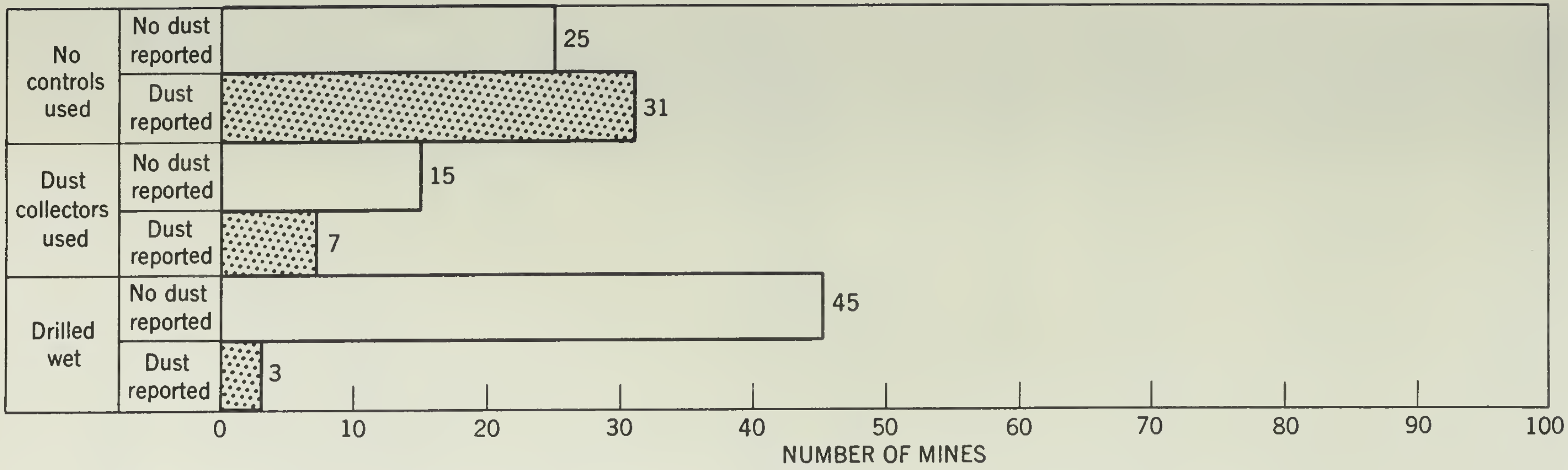


The use and relative effectiveness of dust controls used during percussion drilling in 61 mines.

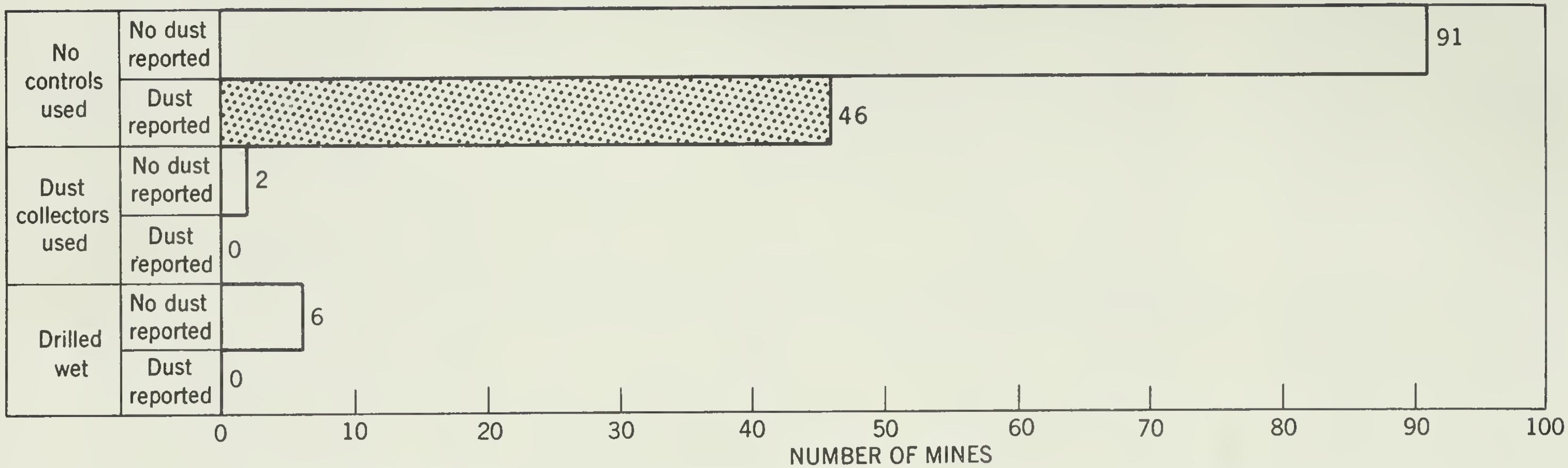


The use and relative effectiveness of dust controls used during rotary drilling in 122 mines.

Figure 4. - Draw-slate drilling.



Use and relative effectiveness of dust controls used during percussion drilling in 126 mines.



Use and relative effectiveness of dust controls used during rotary drilling in 145 mines.

Figure 5. - Bottom drilling.

A proper fit between the collector head and an uneven floor is difficult to obtain, and the use of high-pressure air through the drill steel to blow the cuttings from percussion drill holes makes it difficult for a dust collector to perform efficiently, although if reasonable care is exercised collectors can be made to operate as efficiently on bottom holes as in any other situation.

Bottom generally is drilled to take up bottom rock to give additional height in thin seams, and for the most part, is confined to southern West Virginia, Pennsylvania, and Kentucky. The majority of mines practicing bottom drilling in these States were in classes A, B, and C, and used no controls; those class D mines that did drill bottom employed most of the controls that were observed.

Coal Cutting

Sixty-two percent of the mines covered by this survey cut the coal by machine before blasting. The remaining 38 percent consisted of small mines that blasted off the solid, mines worked by hand, and a few larger mines where continuous mining machines were used exclusively. In the Middle West, a few mines were operated on a semilongwall face where roof pressure breaks down the coal.

For this survey, coal cutting was divided into Bottom cutting and Other than bottom cutting. The latter classification covers considerable variation in types of cutting. A breakdown of Other cutting is given in table 7.

TABLE 7. - Cutting practices in other than bottom in bituminous-coal and lignite mines

Type of cutting	Controls used			No controls used		
	Number of mines	Visible dust		Number of mines	Visible dust	
		Number	Percent		Number	Percent
Top	19	12	63.2	59	41	69.5
Bottom; shear	57	30	52.6	21	17	81.0
Top; shear	60	42	70.0	9	7	77.8
Bottom; top; shear	28	19	67.9	4	1	25.0
Center	2	1	50.0	14	9	64.3
Center; shear	6	0	0	1	1	100.0
Bottom; center	3	3	100.0	4	2	50.0
Shear	1	0	0	2	1	50.0
Total mines		176			114	
Number with visible dust		107			79	
Percent with visible dust		60.8			69.3	

It is recognized that coal cutting is an extremely dusty operation and that the dust clouds produced frequently are very dense, especially in dry coal beds. It is usually in the dry beds that attempts are made to allay the dust. In many instances the control measures used are not entirely effective; however, the dust concentration may be reduced considerably. It would be misleading to correlate the percentage of mines producing visible dust between mines using controls and those using none at all, because of the varying moisture content of the coal beds in different localities.

Figure 6 indicates the use and effectiveness of dust-control measures, and the distribution of mines that used or did not use controls.

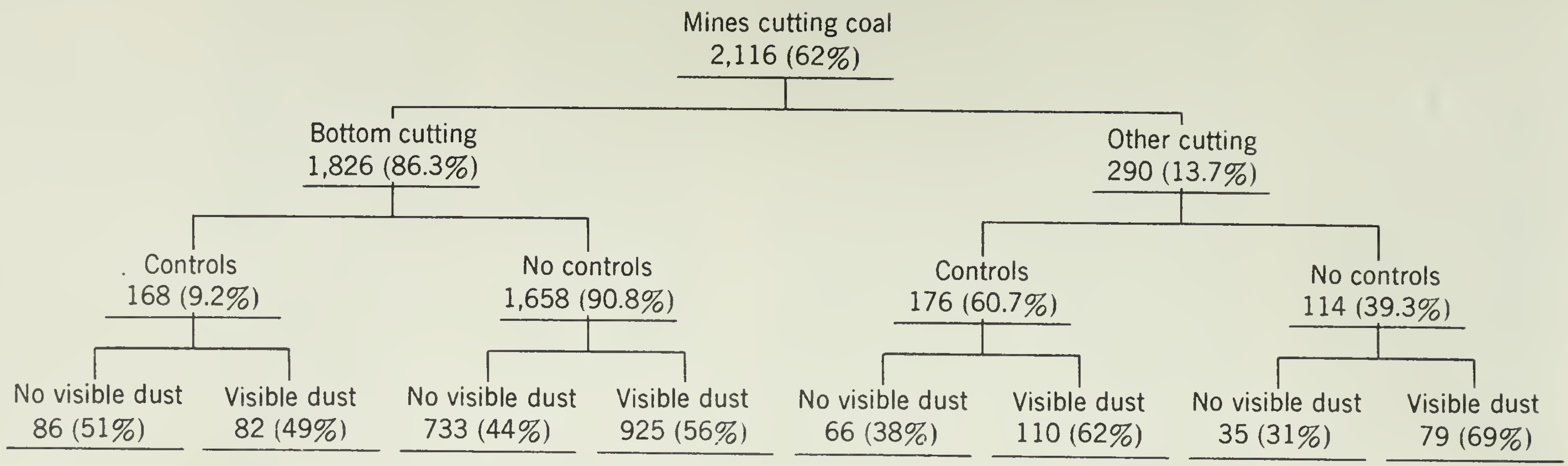


Figure 6. - Use and relative effectiveness of controls during cutting.

Only 16 percent of the mines reported employed dust-control measures while cutting coal. Sixty-one percent used controls when cutting other than bottom, such as top cutting, center cutting, and shearing. Only nine percent of the mines used controls during bottom cutting. This, as well as a lower efficiency in the use of controls in other cutting is to be expected. Tests have demonstrated that, in general, the farther the cuttings have to fall, the denser is the concentration of airborne dust. However, height of coal alone is no criterion of low dust concentrations, for high dust counts have been recorded in low coal and also during bottom cutting. In this survey more than one-half the mines cutting bottom with no controls were observed as dusty.

Dust is controlled by applying water to the machine cuttings as they leave the cut or as they are produced. There are various methods of applying water: Sprays are installed on the cutting machine to wet the material as it leaves the cut or on the cutter bar to wet coal during the cutting operation, and in some mines, hand-held hoses are played on the cutter bar and the cuttings as they leave the kerf. In dry, dusty coal, however, the best of these methods is not usually totally effective. The ineffectiveness of dust-control measures stems largely from improper application of water or lack of understanding of the principles of dust control. Once dust has become airborne, it is almost impossible to wet it and remove it from the air. To control dust satisfactorily it must be wetted before or at the instant it becomes airborne. In general, this involves using a marrow-angle spray that will strike the dust particles as they emerge from the kerf - strike them with enough force to wet them and cause them to impinge against the coal face. The narrow-angle spray consolidates the water and if properly designed will give less opportunity for the dust particles to pass through the spray. It also causes an air current to be set up that aids in carrying the dust particles against the coal face, which has been wetted by the water spray, and will tend to make the particles adhere. A properly designed system will give better control of dust, generally, with less water than a makeshift system.

Some of the factors that influence airborne dust concentrations besides inherent moisture and varying degrees of dustiness in the coal beds are: The height from which the dust falls, the speed at which the cutter chain travels, bit sharpness, rock intrusions, running the cutter bar at excessive speeds while withdrawing or sumping the cutter bar, and the volume of air sweeping the face. The fact that a mine is considered to be naturally wet is no indication that dust-control measures are not needed during cutting, for high dust counts have been obtained when the cutter bar was covered by water as it undercut the coal.

The survey showed that most mines in the leading coal-producing States control dust while cutting coal; for example, in mines in West Virginia, Pennsylvania, and Illinois and in the mines employing more than 100 men in other States. Among the smaller coal-producing States, Utah does a commendable job; in fact, it leads all States in the percentage of mines using control measures during cutting. The survey also evidenced the lack of control measures in many mines cutting at the bottom of the bed and a need for closer supervision of those mines cutting in other than bottom. With adequate application of water, close supervision, and a thorough knowledge of the factors influencing dusty conditions, the dust problems during cutting can be minimized.

TABLE 8. - Cutting practices in bituminous-coal and lignite mines, by States and mine classes, showing the use and relative effectiveness of dust-control measures

State	Mines		Bottom cutting				Other cutting				Shot off solid	Pick mines	All continuous miners
			Controls used		No controls used		Controls used		No controls used				
	Class[1]	Number	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust			
West Virginia (Northern)	A	171	-	-	35	10	1	1	7	1	125	3	-
	B	79	3	3	42	16	10	10	18	17	6	-	-
	C	18	-	-	11	9	5	5	-	-	2	-	-
	D	27	2	0	-	-	21	18	4	4	-	-	-
West Virginia (Southern)	A	39	1	1	12	8	-	-	-	-	25	1	-
	B	76	3	2	63	33	2	1	5	3	3	-	-
	C	61	3	3	49	23	5	3	4	3	-	-	-
	D	148	23	4	90	56	18	8	17	9	-	-	-
Pennsylvania	A	280	3	1	203	93	2	2	2	1	34	32	(2)
	B	103	1	0	81	40	4	2	5	3	3	5	(3)
	C	31	2	0	20	14	6	4	3	3	-	-	-
	D	95	13	3	31	22	39	19	8	8	-	-	4
Kentucky	A	416	1	0	134	82	-	-	5	3	275	1	-
	B	114	1	1	105	62	-	-	5	3	3	-	-
	C	49	4	1	37	31	2	0	5	4	-	1	-
	D	62	4	1	43	28	11	7	4	4	-	-	-
Illinois	A	15	1	0	11	7	1	0	2	1	-	-	-
	B	11	2	2	8	7	-	-	-	-	1	-	-
	C	4	1	1	2	2	1	1	-	-	-	-	-
	D	30	13	13	5	3	8	7	3	1	-	-	1
Virginia	A	298	1	1	100	34	-	-	2	1	190	-	(4)
	B	44	2	0	30	8	2	1	2	0	8	-	-
	C	12	-	-	9	6	-	-	1	1	2	-	-
	D	22	4	1	10	5	5	1	3	3	-	-	-
Alabama	A	178	2	0	77	47	-	-	-	-	98	1	-
	B	14	5	0	5	4	-	-	-	-	3	-	1
	C	8	1	1	5	4	-	-	-	-	2	-	-
	D	18	7	1	6	4	3	2	1	0	1	-	-
Ohio	A	166	2	1	153	95	-	-	-	-	8	2	1
	B	27	-	-	24	20	1	1	1	1	-	-	1
	C	4	1	1	2	1	-	-	-	-	-	-	1
	D	16	5	2	2	2	8	2	-	-	-	-	1
Tennessee	A	307	-	-	22	2	-	-	-	-	283	2	-
	B	15	-	-	11	5	-	-	-	-	4	-	-
	C	13	-	-	13	9	-	-	-	-	-	-	-
	D	17	2	2	14	7	-	-	-	-	1	-	-
Utah	A	20	12	7	6	3	1	0	-	-	1	-	-
	B	4	3	3	-	-	1	0	-	-	-	-	-
	C	7	2	2	-	-	5	4	-	-	-	-	-
	D	7	-	-	-	-	7	6	-	-	-	-	-
Indiana	A	13	-	-	10	8	-	-	-	-	3	-	-
	B	4	-	-	4	4	-	-	-	-	-	-	-
	C	2	-	-	1	1	-	-	1	1	-	-	-
	D	8	1	1	5	5	-	-	2	2	-	-	-
Colorado	A	103	8	5	61	50	-	-	-	-	16	18	-
	B	17	7	5	7	6	2	1	-	-	1	-	-
	C	6	5	4	1	1	-	-	-	-	-	-	-
	D	4	1	1	1	1	1	1	-	-	-	1	-
Group I	A	26	2	0	13	7	-	-	1	1	9	1	-
	B	12	4	2	-	-	2	1	-	-	5	-	1
	C	9	5	2	4	3	-	-	-	-	-	-	-
	D	8	4	4	1	1	2	2	-	-	1	-	-
Group II	A	153	-	-	62	25	-	-	2	1	85	4	-
	B	20	-	-	16	10	-	-	1	0	1	2	-
	C	2	1	0	1	1	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-
	Total	3,413	168	82	1,658	925	176	110	114	79	1,199	74	12
Dust, percent			48.8		55.8		62.5		69.3				[5]12

National total — Breakdown by mine size

Cutting method	Class A			Class B			Class C			Class D		
	Number	Visible dust	Percent	Number	Visible dust	Percent	Number	Visible dust	Percent	Number	Visible dust	Percent
Bottom, controls used	33	16	48.5	31	18	58.1	25	15	60.0	79	33	41.8
Bottom, no controls used	899	471	52.4	396	215	54.3	155	105	67.7	208	134	64.4
Other cutting, controls used ..	5	3	60.0	24	17	70.8	24	17	70.8	123	73	59.3
Other cutting, no controls used	21	9	42.9	37	27	73.0	14	12	85.7	42	31	73.8

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more. 2/ Class A mines used 1 auger-type machine, and 3 mines used pneumatic picks. 3/ Class B mines; 2 mines used auger-type machines, and 1 mine used pneumatic picks.
4/ Five class A mines used auger-type machines. 5/ 12 mines used other cutting methods.

Blasting

Table 9 contains information on blasting procedure, explosives used to break down the coal face, personnel involved, and the extent of ventilation and wetting used to control dust and smoke during and after blasting.

For the greater part the coal face was shot by certified shot firers in the larger mines and by workmen in the smaller mines. Ninety-three percent of the shooting was done during the working shift; this percentage includes many of the small mines that blasted off the solid.

Some mines, especially the larger ones, wetted down the broken coal with a hose after blasting to prevent the dust from becoming airborne during loading. In Washington a few mines used a fog gun during and after the blasting operation that utilized compressed air and water to spray the coal with fine mist. This practice is reported to be effective in lowering the amount of airborne dust produced by blasting and loading.26/

Dust and smoke were visible when men returned to the face after blasting, especially in some smaller mines. This was because men returned too quickly, or there was not enough ventilation to carry away the smoke and dust. Inadequate ventilation was reported in those mines that used natural ventilation and in some mines that carried the ventilation only to the last crosscut.

Of the coal-breaking agents, permissible explosives were used in the greater proportion of the mines. Black blasting powder was confined to the smaller mines, and compressed air and carbon dioxide were used to a lesser extent in the larger mines. One mine was reported using a new chemical coal breaker.

Loading

Coal was loaded by hand in approximately three-fourths of the mines covered in this survey; however, these mines represented only a small proportion of the total coal production and the total number of men employed in the coal industry of the United States. Only 1 percent of the mines loading coal by hand used control measures. Many of the small mines were reported to be naturally damp or wet; this condition varied from State to State, and controls were not considered necessary in this case. Hand loading is not an extremely dusty operation; but in dry, dusty mines that lack proper ventilation, airborne dust may become extremely concentrated. Sprinkling coal before or during hand loading proved effective; only 1 out of the 25 hand-loading mines using this method of dust control was reported as having visible dust. In view of this effectiveness, more mines should attempt to wet coal before or during hand loading.

The bulk of the coal produced in the United States is loaded mechanically, and mechanical loading was used exclusively in 20 percent of the mines surveyed. Because of rougher handling, mechanical loading produces considerably more dust than hand loading. This is caused by the loading actions of the machines and the conveyors dumping the coal into shuttle cars or mine cars. Probably the dustiest operation is loading cuttings or "bug dust" produced during the cutting operation. Only 16 percent of the mines loading coal mechanically used control measures during loading. Controls consisted mainly of hand-held hoses, which wetted the coal before the loading machine entered the place to be loaded out, and/or sprays mounted on the loading machine, which wetted the coal during loading (see fig. 7). Another means of allaying dust practiced by some mines is to wet mine cars before they are loaded. The wet sides of the cars will trap considerable dust as the coal is discharged from the loader into the mine car.

26/ McGuire, L. H., How Fog Guns and Multiple Shooting Promote Dust and Fume Control: Coal Age, vol. 57, 1952, pp. 108-110.

TABLE 9. - Blasting practices and types of explosives used in bituminous-coal and lignite mines, by States and mine classes

State	Class[1/]	Number of mines	Blasting practice							Blasting agents									
			Shot by shot firers	Shot by miners	Shot on shift	Shot off shift	Wetted after blasting	Need ventilation	Visible dust and smoke[2/]	Permissible explosives	Comp-air or Airdox	Cardox	Permissible and Airdox[3/]	Permissible and Cardox[3/]	Black powder or dynamite	Permissible with cap and fuse	Permissible and black powder[3/]	No blasting	Chemical coal breakers
West Virginia (Northern)	A	171	10	158	168	-	-	11	39	167	-	1	-	-	-	-	-	3	-
	B	79	32	47	78	1	-	9	24	78	-	-	-	1	-	-	-	-	-
	C	18	9	9	18	-	-	4	6	18	-	-	-	-	-	-	-	-	-
	D	27	26	1	27	-	2	1	3	27	-	-	-	-	-	-	-	-	-
West Virginia (Southern)	A	39	13	26	37	2	-	-	3	39	-	-	-	-	-	-	-	-	-
	B	76	51	25	74	2	3	-	2	66	4	2	2	2	-	-	-	-	-
	C	61	48	13	61	-	4	-	9	47	8	2	3	1	-	-	-	-	-
	D	148	120	28	148	-	22	2	9	115	12	3	11	7	-	-	-	-	-
Pennsylvania	A	280	23	256	273	6	1	13	38	254	-	-	-	1	22	-	2	1	-
	B	103	25	76	99	2	1	1	2	100	-	-	-	1	-	-	-	2	-
	C	31	17	14	31	-	3	-	1	29	-	-	1	1	-	-	-	-	-
	D	95	84	10	91	3	25	1	13	81	4	-	4	5	-	-	-	1	-
Kentucky	A	416	245	169	413	1	-	31	75	400	1	-	-	-	4	9	-	2	-
	B	114	90	24	96	18	-	-	10	107	4	1	1	-	-	-	-	-	-
	C	49	44	4	48	-	1	2	4	42	2	-	1	3	-	-	-	1	-
	D	62	51	11	62	-	5	3	6	51	4	-	5	2	-	-	-	-	-
Illinois	A	15	13	2	2	13	-	-	1	6	2	-	-	-	6	-	1	-	-
	B	11	11	-	6	5	-	1	5	6	5	-	-	-	-	-	-	-	-
	C	4	4	-	3	1	1	-	1	-	3	-	1	-	-	-	-	-	-
	D	30	29	-	22	7	3	4	12	5	20	-	3	-	-	-	-	1	1
Virginia	A	298	203	95	292	6	-	5	13	244	-	-	-	-	17	37	-	-	-
	B	44	36	8	44	-	-	-	-	43	1	-	-	-	-	-	-	-	-
	C	12	9	3	12	-	-	-	-	10	1	-	1	-	-	-	-	-	-
	D	22	17	5	22	-	2	-	1	19	-	-	-	3	-	-	-	-	-
Alabama	A	178	29	148	158	19	-	21	3	126	-	-	-	-	48	-	3	1	-
	B	14	9	4	13	-	2	-	-	13	-	-	-	-	-	-	-	1	-
	C	8	6	2	7	1	1	-	-	8	-	-	-	-	-	-	-	-	-
	D	18	15	3	17	1	7	-	-	18	-	-	-	-	-	-	-	-	-
Ohio	A	166	10	155	159	6	-	22	22	33	-	-	-	-	132	-	-	1	-
	B	27	7	19	26	-	-	-	6	26	-	-	-	-	-	-	-	1	-
	C	4	2	2	4	-	-	-	-	4	-	-	-	-	-	-	-	-	-
	D	16	14	1	15	-	3	-	2	6	8	1	-	-	-	-	-	1	-
Tennessee	A	307	10	295	305	-	-	13	40	238	-	-	-	-	58	2	7	2	-
	B	15	8	7	13	2	-	-	1	15	-	-	-	-	-	-	-	-	-
	C	13	8	5	13	-	-	1	1	13	-	-	-	-	-	-	-	-	-
	D	17	8	9	17	-	-	-	-	17	-	-	-	-	-	-	-	-	-
Utah	A	20	19	1	5	15	12	2	2	20	-	-	-	-	-	-	-	-	-
	B	4	4	-	4	-	4	-	-	4	-	-	-	-	-	-	-	-	-
	C	7	7	-	7	-	7	-	1	5	-	-	2	-	-	-	-	-	-
	D	7	7	-	6	1	7	-	2	7	-	-	-	-	-	-	-	-	-
Indiana	A	13	11	2	13	-	-	-	-	6	-	-	-	-	7	-	-	-	-
	B	4	4	-	1	3	-	-	-	3	1	-	-	-	-	-	-	-	-
	C	2	2	-	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-
	D	8	8	-	5	3	2	-	7	-	4	-	4	-	-	-	-	-	-
Colorado	A	103	88	-	66	22	3	1	4	79	-	3	-	6	-	-	-	15	-
	B	17	17	-	15	2	9	-	-	8	-	-	-	9	-	-	-	-	-
	C	6	6	-	6	-	5	-	-	2	2	-	-	2	-	-	-	-	-
	D	4	3	-	2	1	2	-	-	1	-	-	-	2	-	-	-	1	-
Group I	A	26	18	8	19	7	-	-	1	17	-	2	-	-	6	-	1	-	-
	B	12	11	1	9	3	4	-	-	11	-	1	-	-	-	-	-	-	-
	C	9	9	-	7	2	3	-	1	8	-	-	-	1	-	-	-	-	-
	D	8	7	1	7	1	7	-	-	8	-	-	-	-	-	-	-	-	-
Group II	A	153	76	68	77	67	2	-	-	86	-	3	1	-	54	-	-	9	-
	B	20	11	2	5	8	1	-	-	11	-	1	-	-	-	-	-	7	-
	C	2	2	-	2	-	1	-	-	-	1	-	1	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Class totals	A	2,185	768	1,383	1,987	164	18	119	241	1,715	3	9	1	7	354	48	14	34	-
	B	540	316	213	483	46	24	11	50	491	15	5	3	13	-	-	-	11	-
	C	226	173	52	221	4	26	7	24	186	19	2	10	8	-	-	-	1	-
	D	462	359	69	441	17	87	11	55	355	52	4	27	19	-	-	-	4	1
Grand totals		3,413	1,646	1,717	3,132	231	155	148	370	2,747	89	20	41	47	354	48	14	50	1

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.
2/ Visible dust and smoke when men return to place.
3/ 2 blasting agents used at different points in the same mine.

Figure 7. - Water sprays used to allay dust at discharge from loading machine.

Although many mines were reported as not using controls before or during loading, the coal may have been wetted after blasting and may also have been wetted during cutting. This would tend to curb considerable dust during the loading of coal or machine cuttings.

Approximately 5 percent of the mines used both hand and mechanical means to load coal. The data on hand and mechanical loading are almost identical to those for mechanical loading in respect to use and effectiveness of control measures. With both methods 54-60 percent of the mines using no controls were reported to have visible dust, and control measures were reported to be 60-65 percent effective. The questionnaire did not yield information on the proportion of the coal in these mines that was loaded mechanically, but it probably made up the greater part of their tonnage.

A breakdown of the loading operation follows (fig. 8), showing the number of mines in each type of loading, those mines using or not using controls, and the relative effectiveness of the control measures used.

Continuous-Type Mining Machines

The advent of the continuous-type mining machine introduced an enhanced dust problem in the coal-mining industry, as it combines cutting, face drilling, blasting, and loading into one operation, thereby generally producing dense clouds of airborne dust. The coal produced by the machines is not as coarse as that produced by conventional mining machines, and the fine dust is more likely to become airborne. To maintain a continuous operation, the machines often are followed by a conventional loader or a shuttle car used as a surge bin. This results in more handling of the coal, more spillage on the bottom to be pulverized by moving equipment, and, consequently, increased dustiness.

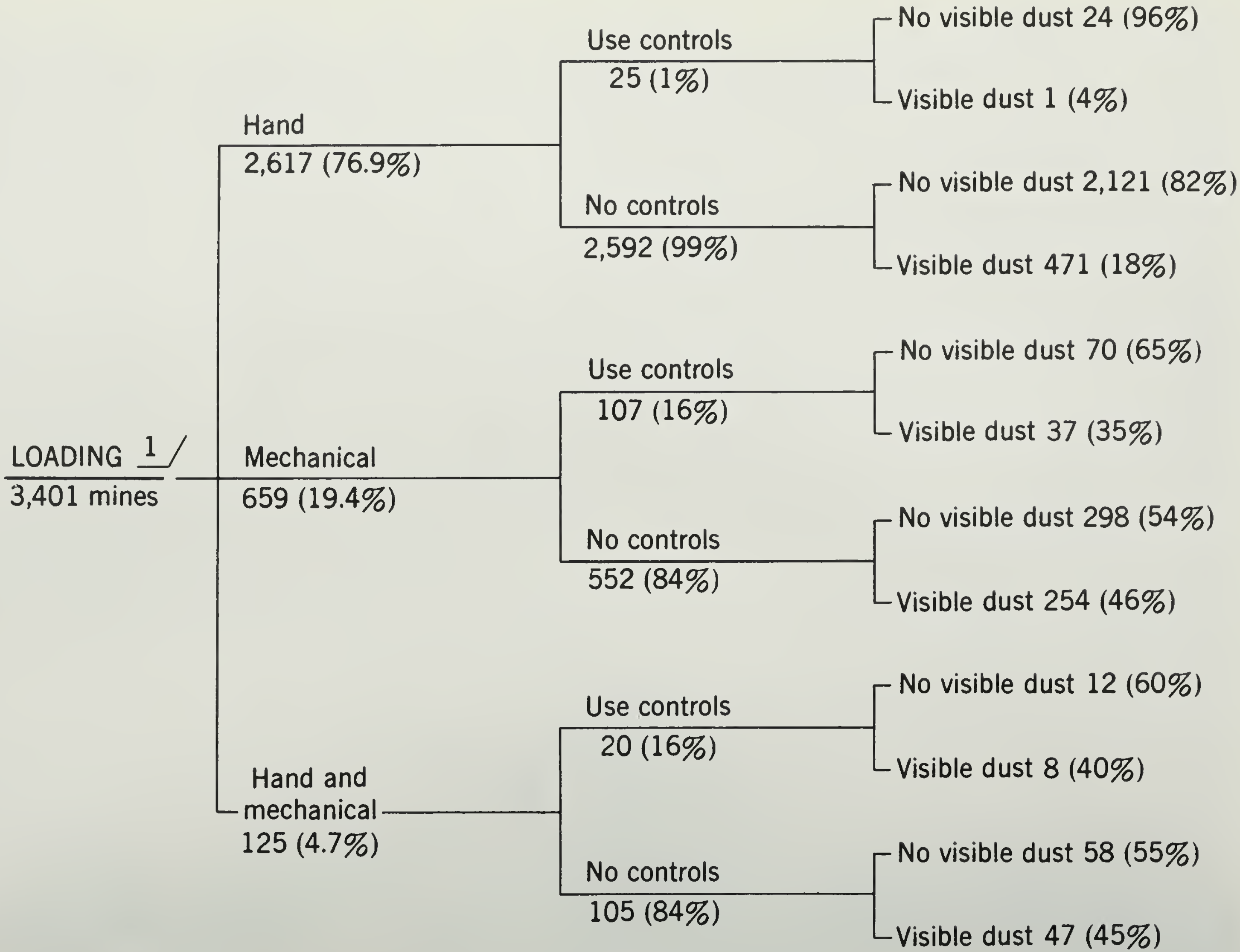
To combat dusty conditions, the machines covered by this survey were equipped with an average of 4 sprays with water pressures varying from 100 to 400 p.s.i. Most sprays were mounted on the head; however, a few were reported to have been placed on each side of the boom. In addition to the sprays in most mines, a large volume of air was conducted to the face. A few of the mines used a wetting agent to help allay dust. One mine in Pennsylvania, in addition to sprays on the machine, placed sprays at the last crosscut on the return side of the line brattice.

Although all the continuous-type mining machines were equipped with sprays and most mines carried ventilation to the face, visible dust was observed in 76 percent of the mines in which the machines were used.

Transportation

During the underground handling and transportation of coal from the face regions to the dump or tipple, significant concentrations of airborne dust can be produced at a number of points. The point of transfer from one form of transportation to another was reported as the chief source of dust.

Generally, controls were not used at these transfer and discharge points, and dust clouds were visible in many instances. For example, only 20 percent of the mines used controls at shuttle-car discharge points, and over half of the controls appeared ineffective. Of the mines not using controls, nearly half were reported as having dusty conditions at shuttle-car discharge points.



1/ Does not include 12 mines using continuous-type mining machines exclusively.

Figure 8. - A breakdown of loading practices, showing the use and relative effectiveness of control measures.

TABLE 10. - Loading practices in bituminous-coal and lignite mines, by States and mine classes, showing the use and relative effectiveness of dust-control measures

State	Mines		Hand loading				Mechanical loading				Hand and mechanical loading				
			No controls		Controls		No controls		Controls		No controls		Controls		
	Class[1/]	Number	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Number	Visible dust	Continuous miners
West Virginia (Northern)	A	171	157	4	-	-	12	4	-	-	2	0	-	-	
	B	79	56	5	-	-	20	9	-	-	2	1	1	0	
	C	18	10	1	-	-	8	5	-	-	-	-	-	-	
	D	27	1	1	-	-	23	16	3	2	-	-	-	-	
West Virginia (Southern)	A	39	34	7	-	-	5	1	-	-	-	-	-	-	
	B	76	38	8	-	-	32	9	3	0	2	0	1	0	
	C	61	15	2	1	0	35	14	2	0	8	1	-	-	
	D	148	32	6	1	0	61	31	22	6	26	9	6	2	
Pennsylvania	A	280	259	32	2	0	15	4	1	0	3	3	-	-	
	B	103	81	11	-	-	16	2	1	0	4	1	-	-	1
	C	31	16	6	1	0	9	4	3	1	1	1	1	0	
	D	95	25	10	1	0	31	9	18	11	15	7	3	2	2
Kentucky	A	416	399	151	1	0	16	8	-	-	-	-	-	-	
	B	114	83	22	1	0	30	14	-	-	-	-	-	-	
	C	49	22	9	-	-	23	12	1	0	3	3	-	-	
	D	62	12	5	2	0	35	15	-	-	12	6	1	0	
Illinois	A	15	7	4	-	-	6	3	2	0	-	-	-	-	
	B	11	7	5	-	-	4	4	-	-	-	-	-	-	
	C	4	-	-	-	-	3	3	1	1	-	-	-	-	
	D	30	2	1	-	-	27	24	-	-	-	-	-	-	1
Virginia	A	298	293	7	3	0	2	0	-	-	-	-	-	-	
	B	44	35	1	-	-	8	0	-	-	1	0	-	-	
	C	12	3	1	-	-	7	2	-	-	2	0	-	-	
	D	22	5	1	-	-	10	3	-	-	6	2	1	1	
Alabama	A	178	176	26	-	-	2	0	-	-	-	-	-	-	
	B	14	8	4	-	-	3	1	2	0	-	-	-	-	1
	C	8	5	2	-	-	1	0	-	-	1	1	1	1	
	D	18	4	3	1	0	2	1	10	0	1	1	-	-	
Ohio	A	166	150	29	1	0	10	4	1	0	3	1	-	-	1
	B	27	20	3	1	0	4	3	-	-	1	1	-	-	1
	C	4	2	0	-	-	-	-	-	-	1	0	-	-	1
	D	16	-	-	-	-	11	2	3	0	1	1	-	-	1
Tennessee	A	307	306	14	-	-	1	1	-	-	-	-	-	-	
	B	15	13	2	-	-	2	0	-	-	-	-	-	-	
	C	13	4	0	-	-	4	2	-	-	5	5	-	-	
	D	17	9	2	-	-	7	4	-	-	1	0	-	-	
Utah	A	20	6	4	-	-	7	5	7	3	-	-	-	-	
	B	4	-	-	-	-	1	1	3	3	-	-	-	-	
	C	7	-	-	-	-	-	-	7	4	-	-	-	-	
	D	7	-	-	-	-	1	1	6	4	-	-	-	-	
Indiana	A	13	8	2	-	-	5	4	-	-	-	-	-	-	
	B	4	2	2	-	-	2	2	-	-	-	-	-	-	
	C	2	-	-	-	-	2	2	-	-	-	-	-	-	
	D	8	-	-	-	-	6	6	2	0	-	-	-	-	
Colorado	A	103	87	45	4	1	12	7	-	-	-	-	-	-	
	B	17	6	4	1	0	5	3	2	0	1	1	2	1	
	C	6	2	2	-	-	3	1	-	-	1	1	-	-	
	D	4	2	1	-	-	1	1	-	-	-	-	1	0	
Group I	A	26	19	[illegible]	-	-	6	2	1	0	-	-	-	-	
	B	12	5	3	-	-	4	1	1	0	-	-	-	-	2
	C	9	4	2	2	0	-	-	2	1	1	0	-	-	
	D	8	1	0	2	0	-	-	2	1	-	-	2	1	1
Group II	A	153	144	11	-	-	9	3	-	-	-	-	-	-	
	B	20	17	4	-	-	1	0	1	0	1	1	-	-	
	C	2	-	-	-	-	2	1	-	-	-	-	-	-	
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Total	3,413	2,592	471	25	1	552	254	107	37	105	47	20	8	12

National totals		Class A[1/]			Class B[1/]			Class C[1/]			Class D[1/]		
		Number	Visible dust	Dust, percent	Number	Visible dust	Dust, percent	Number	Visible dust	Dust, percent	Number	Visible dust	Dust, percent
Hand loading	No controls	2,045	342	16.7	371	74	19.9	83	25	30.1	93	30	32.3
	Controls	11	1	9.1	3	0	0	4	0	0	7	0	0
Mechanical loading	No controls	108	46	42.6	132	49	37.1	97	46	47.4	215	113	52.6
	Controls	12	3	25.0	13	3	23.1	16	7	43.8	66	24	36.4
Hand and mechanical loading	No controls	8	4	50.0	12	5	41.7	23	12	52.2	62	26	41.9
	Controls	-	-	-	4	1	25.0	2	1	50.0	14	6	42.9

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.

TABLE 11. - Use of continuous-type mining machines in bituminous-coal and lignite mines, by States and mine classes, showing methods used to allay airborne dust

State	Class[1/]	Mines using continuous miners	Methods of dust control			
			Brattice to face	Auxiliary fans	Wetting	Visible dust
West Virginia (Northern)	B	1	-	-	1	1
	D	5	2	-	5	4
West Virginia (Southern)	B	1	-	-	1	0
	D	8	5	-	8	6
Pennsylvania	B	2	1	-	2	0
	C	2	2	-	2	2
	D	33	24	-	33	25
Kentucky	B	1	-	-	1	1
	C	2	-	2	2	2
	D	3	-	-	3	3
Illinois	D	4	1	-	4	4
Virginia	C	1	1	-	1	0
Alabama	B	1	1	-	1	1
	D	3	2	-	3	1
Ohio	A	1	1	-	1	1
	B	1	1	-	1	1
	C	1	-	-	1	1
	D	3	1	-	3	1
Utah	D	1	1	-	1	1
Indiana	D	1	-	-	1	0
Colorado	B	1	-	1	1	1
	C	2	-	1	2	2
Wyoming	D	1	1	1	1	1
Washington	B	2	2	-	2	2
	D	1	1	-	1	1
National class total	A	1	1	-	1	1
	B	10	5	1	10	7
	C	8	3	3	8	7
	D	63	38	1	63	47
Grand total		82	47	5	82	62

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.

Some dust was reported as visible during transportation. In a few mines the coal in cars or on conveyors was wetted during transportation (fig. 9). Dust was

Figure 9. - Spraying water on loaded mine car before leaving the side track.

reported in some cases on the mine-car haulageways, but the questionnaire did not reveal whether the source of the dust was the roadbed, traction sand, or the mine cars, which may have been overloaded or not tight; 2.4 percent of the mines wetted the coal during transportation, 25 percent of the mines used tight cars, and 10 percent of the mines overloaded the mine cars.

Nearly all mines employing more than 14 men cleaned up the loose coal on haulageways, and only 10 percent of the class A mines did not. Water and chemicals, such as salt and calcium chloride, were used on very few track haulageways, and such use was mostly in large mines. Chemicals were used on the main haulage in a considerable number of small mines in Virginia, but these mines used rubber-tired mine cars to transport the coal from the tipple to an outside dumping point. The shuttle-car runways were wetted or treated with chemicals to allay dust and consolidate the runway in the larger mines.

Tipples and Cleaning Plants

Other significant sources of airborne dust in the coal industry are the preparation and handling of coal after it leaves the mine. The installations covered in this survey ranged from simple mine car-to-truck dumps to large elaborate cleaning plants. In all instances the preparation pattern is much the same; and wherever coal is dumped, screened, crushed, or transported dust is produced, and dry coal will greatly enhance the dust concentrations produced by these operations.

Some plants have no dust problem, as their coal comes from the mine damp enough to prevent much dust from becoming airborne. Others have a tremendous problem. Crushing and screening operations were reported as the most common producers of visible airborne dust; however, conveyor discharge points, chutes, air cleaners, loading booms, and various other means of handling the coal also produced visible dust clouds.

Many plants used some form of control at one or more locations but also needed controls at other points. In tabulating the data the mines have been divided as to the use of controls and their relative effectiveness as determined by observation. The most widely used form of dust control was a water spray to wet the coal. Vacuum collectors, exhaust fans and hoods, and steam jets also were used. In the few instances in which it was used steam was reported as being very effective. In a few preparation plants water for spraying had a wetting agent added to it, and these sprays were reported to be quite effective.

Settled dust was cleaned by broom and shovel in most plants; however, many mines also washed down the plants with hoses when weather permitted, and a few of the modern preparation plants used vacuum cleaners. Virtually all mines kept the floors and ledges of the preparation plants relatively free from settled dust.

In general, a need was indicated for more control measures in tipples and preparation plants and closer supervision to obtain maximum effectiveness from these control measures.

TABLE 13. - Dust-control practices in tipples and cleaning plants of bituminous-coal and lignite mines, by States and mine classes

State	Class[1]	Number of mines	Tipple and cleaning plant — Outside controls: Controls used effectively	Controls used ineffectively	Controls effective, but others needed	No controls and visible dust	No controls, dust at dumping point	No controls used or needed	No tipple, central plant
West Virginia (Northern)	A	171	-	-	-	3	4	163	1
	B	79	-	3	1	13	6	51	5
	C	18	-	1	1	7	1	6	2
	D	27	5	6	6	9	-	-	1
West Virginia (Southern)	A	39	-	1	-	2	5	28	3
	B	76	3	2	2	8	6	35	20
	C	61	6	4	4	17	1	15	14
	D	148	30	19	13	44	7	23	12
Pennsylvania	A	280	-	1	-	5	36	237	1
	B	103	-	2	-	15	13	68	5
	C	31	3	-	-	11	4	12	1
	D	95	34	5	12	26	-	14	4
Kentucky	A	416	-	1	-	5	141	264	5
	B	114	2	-	2	27	24	51	8
	C	49	1	2	3	24	6	8	5
	D	62	7	6	5	29	1	6	8
Illinois	A	15	-	-	-	2	6	7	-
	B	11	-	-	-	8	1	2	-
	C	4	-	-	-	4	-	-	-
	D	30	5	5	11	9	-	-	-
Virginia	A	298	-	-	-	2	12	284	-
	B	44	-	-	1	5	4	31	3
	C	[illegible]	[illegible]		1	[illegible]		[illegible]	1

TABLE 12. - Use and relative effectiveness of dust-control measures during transportation in bituminous-coal and lignite mines, by States and mine classes; also the extent of application of water and chemicals to haulageways

	Mine cars								Shuttle cars							Conveyors								Haulageways			
	Mines		Wetted during transport	Cars overloaded	Cars tight	Dust visible		No cars	Mines using shuttle cars		Cars overloaded	Shuttle car discharge				Mines using conveyors		Wetted during transport	Conveyors overloaded	Transfer or dumping points				Wetted		Chemicals	
						Haulageways	Narrow airways					Controls used		No controls						Controls used		No controls		Main haulage	Shuttle car haulage	Main haulage	Shuttle car haulage
State	Class 1/	Number							Number	Percent		No dust	Visible dust	No dust	Visible dust	Number	Percent			No dust	Visible dust	No dust	Visible dust				
West Virginia	A	171	-	3	2	1	-	3	2	1.2	-	-	-	1	1	2	1.2	-	-	-	-	2	-	-	1	-	-
(Northern)	B	79	1	5	8	-	-	15	13	16.5	-	1	-	10	2	14	17.7	1	1	1	2	8	3	-	1	-	1
	C	18	-	2	1	-	-	2	5	27.8	-	1	-	2	2	3	16.7	-	-	1	1	-	1	-	-	-	-
	D	27	4	2	7	4	-	-	17	63.0	-	1	8	3	5	3	11.1	-	-	-	1	1	1	4	7	1	1
West Virginia	A	39	-	-	13	1	-	5	4	10.3	1	-	-	4	-	5	12.8	-	1	-	1	2	2	-	-	-	-
(Southern)	B	76	1	6	28	2	-	17	15	19.7	-	-	-	12	3	25	32.9	2	-	3	-	16	6	-	1	-	2
	C	61	4	11	25	3	-	11	28	45.9	3	2	3	14	9	21	34.4	3	2	4	4	7	6	-	2	1	5
	D	148	14	15	76	9	-	13	66	44.6	9	12	9	36	9	65	44.0	8	2	15	18	26	6	9	9	4	13
Pennsylvania	A	280	2	9	38	4	-	3	4	1.4	1	-	-	2	2	27	9.6	1	-	-	1	18	8	2	-	1	-
	B	103	1	15	13	3	4	3	9	8.7	6	3	-	4	2	22	21.4	1	-	2	1	15	4	-	2	-	2
	C	31	1	2	6	1	-	2	10	32.3	-	2	2	6	-	17	54.8	1	-	4	1	7	5	-	2	-	2
	D	95	17	19	48	12	3	2	55	57.9	-	7	9	28	11	31	32.6	5	-	3	12	9	7	6	18	3	13
Kentucky	A	416	-	119	29	60	-	18	19	4.6	4	-	1	14	4	10	2.4	-	-	-	1	5	4	-	-	-	-
	B	114	1	24	13	2	1	8	17	14.9	3	-	3	9	5	23	20.2	-	-	-	3	10	10	-	-	-	2
	C	49	1	12	5	5	1	4	19	38.8	2	-	4	8	7	13	26.5	1	-	1	4	5	3	1	2	-	4
	D	62	4	9	21	9	4	6	30	48.4	-	3	2	18	7	32	50.0	5	-	10	8	10	4	6	3	2	12
Illinois	A	15	-	-	5	-	-	1	5	33.3	-	-	-	2	3	-	-	-	-	-	-	-	-	1	-	1	2
	B	11	-	-	3	1	-	1	3	27.3	-	-	-	1	2	2	18.2	-	-	-	2	-	-	3	-	-	1
	C	4	1	1	1	1	-	-	4	100.0	-	-	1	1	2	-	-	-	-	-	-	-	-	1	-	-	3
	D	30	-	1	5	4	-	8	24	80.0	3	-	3	8	13	12	40.0	1	-	3	3	2	4	6	-	1	18
Virginia	A	299	-	16	152	22	-	2/22	20	6.7	2	-	-	18	2	8	2.7	-	-	-	-	7	1	-	-	3/19	2
	B	44	-	5	15	2	-	4	6	13.6	-	-	-	5	1	5	11.4	-	-	-	-	5	-	-	-	1	2
	C	12	-	-	6	2	-	-	4	33.3	-	1	-	2	1	4	33.3	-	-	-	-	2	2	1	1	-	1
	D	22	1	1	7	1	-	-	14	63.6	-	-	-	12	2	7	31.8	-	-	1	1	4	1	-	-	-	5
Alabama	A	178	-	4	64	2	-	2	-	-	-	-	-	-	-	22	12.4	1	-	1	1	12	8	1	-	-	-
	B	14	-	1	4	2	-	1	3	21.4	-	1	-	2	-	3	21.4	-	-	-	-	2	1	-	1	-	-
	C	8	-	-	3	1	-	-	1	12.5	-	-	-	1	-	3	37.5	-	-	1	1	1	-	-	-	-	-
	D	18	4	2	14	1	-	-	9	50.0	-	3	3	3	-	4	22.2	-	-	2	1	1	-	3	1	-	-
Ohio	A	166	-	18	30	1	-	2	3	1.8	-	-	-	3	-	11	6.6	-	-	1	-	8	2	-	-	-	-
	B	27	-	-	12	-	-	1	-	-	-	-	-	-	-	5	18.5	-	-	-	-	3	2	-	-	-	-
	C	4	-	-	-	-	-	-	1	25.0	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	16	3	-	8	-	-	1	10	62.5	-	1	1	7	1	5	31.3	3	-	4	-	1	-	-	-	-	-
Tennessee	A	307	-	10	24	5	-	2	1	0.3	-	-	-	-	1	4	1.3	-	-	-	-	4	-	-	-	-	-
	B	15	-	1	-	3	-	-	-	-	-	-	-	-	-	3	20.0	-	-	-	-	1	2	-	-	-	-
	C	13	-	2	1	1	-	1	6	46.2	-	-	-	5	1	4	30.8	-	-	-	-	3	1	-	-	-	-
	D	17	1	4	1	2	-	-	4	23.5	1	-	2	-	2	7	41.2	-	1	2	1	-	4	-	1	-	-
Utah	A	20	2	2	3	2	-	9	9	45.0	-	-	2	6	1	6	30.0	-	-	-	2	-	4	6	1	1	-
	B	4	1	-	1	-	-	2	3	75.0	-	1	-	1	1	2	50.0	-	-	-	-	-	2	1	-	1	-
	C	7	2	-	2	1	-	-	6	85.7	-	1	-	4	1	2	28.6	-	-	-	-	1	1	2	-	-	-
	D	7	3	1	5	1	-	-	7	100.0	-	-	-	7	-	2	28.6	-	-	-	-	2	-	1	2	-	-
Indiana	A	13	-	-	7	3	-	-	1	7.7	-	-	-	-	1	-	-	-	-	-	-	-	-	2	-	-	-
	B	4	-	-	2	-	-	1	2	50.0	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	2
	C	2	-	-	1	-	-	-	2	100.0	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2
	D	8	-	1	7	3	-	-	7	87.5	1	2	-	2	3	1	12.5	-	-	-	-	-	1	4	1	-	4
Colorado	A	103	-	-	30	3	-	1	4	3.9	-	-	-	3	1	28	27.2	-	-	-	-	17	11	-	-	-	-
	B	17	-	-	1	2	-	1	4	23.5	-	-	-	3	1	8	47.1	-	-	-	1	3	4	3	1	-	-
	C	6	-	-	3	-	-	1	3	50.0	-	-	-	-	3	5	83.3	-	-	-	-	1	4	-	1	-	-
	D	4	3	-	2	-	-	-	2	50.0	-	-	-	2	-	2	50.0	1	-	1	-	1	-	2	2	-	-
Group I	A	26	-	1	5	-	-	-	-	-	-	-	-	-	-	3	11.5	-	-	-	-	1	2	-	-	-	-
	B	12	-	1	1	-	-	1	1	8.3	-	-	-	1	-	5	41.7	-	-	-	2	2	1	1	-	-	-
	C	9	1	-	5	1	-	-	2	22.2	-	-	1	1	-	5	55.6	1	-	1	1	2	1	1	-	-	-
	D	8	2	-	5	2	-	-	2	25.0	-	-	-	1	1	4	50.0	1	-	-	-	3	1	2	-	-	-
Group II	A	153	2	1	33	1	-	2	1	0.7	-	-	-	1	-	6	3.9	-	-	-	-	6	-	16	1	-	-
	B	20	-	-	6	-	-	-	1	5.0	-	-	-	1	-	1	5.0	-	-	-	-	1	-	6	1	-	-
	C	2	1	-	2	-	-	-	1	50.0	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total		3,413	78	326	809	186	13	176	489	14.3	36	43	55	276	115	502	14.7	36	7	61	74	237	130	92	62	36	99
Percent			4/2.4	4/10.1	4/25.0	4/5.7	4/0.4	5/5.2			6/7.3	8.8	11.2	56.5	23.5			7/7.2	1.4	12.2	14.7	47.2	25.9				
National	A	2,185	6	183	435	105	0	70	73	3.3	8	-	3	54	16	132	6.1	2	1	2	6	82	42	28	3	22	4
totals by	B	540	5	58	107	17	5	55	77	14.3	9	6	4	49	18	118	21.9	4	1	6	11	66	35	14	7	2	12
class	C	226	11	30	61	16	1	21	92	40.7	5	8	11	46	27	77	34.1	6	2	12	12	29	24	7	8	1	17
	D	462	56	55	206	48	7	30	247	53.5	14	29	37	127	54	175	37.7	24	3	41	45	60	29	43	44	11	66

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.
2/ In Virginia 49 Class A mines and 5 Class B mines used rubber-tired mine cars.
3/ Rubber-tired mine cars.
4/ These percentages are of those mines using mine cars (3,237).
5/ These percentages are of all mines (3,413).
6/ These percentages are of those mines using shuttle cars (489).
7/ These percentages are of those mines using conveyors (502).

TABLE 13. - Dust-control practices in tipples and cleaning plants of bituminous-coal and lignite mines, by States and mine classes

		Tipple and cleaning plant Outside controls							
State	Class[1/]	Number of mines	Controls used effec- tively	Controls used ineffectively	Controls effective, but others needed	No controls and visible dust	No controls, dust at dump- ing point	No controls used or needed	No tipple, central plant
West Virginia (Northern)	A	171	-	-	-	3	4	163	1
	B	79	-	3	1	13	6	51	5
	C	18	-	1	1	7	1	6	2
	D	27	5	6	6	9	-	-	1
West Virginia (Southern)	A	39	-	1	-	2	5	28	3
	B	76	3	2	2	8	6	35	20
	C	61	6	4	4	17	1	15	14
	D	148	30	19	13	44	7	23	12
Pennsylvania	A	280	-	1	-	5	36	237	1
	B	103	-	2	-	15	13	68	5
	C	31	3	-	-	11	4	12	1
	D	95	34	5	12	26	-	14	4
Kentucky	A	416	-	1	-	5	141	264	5
	B	114	2	-	2	27	24	51	8
	C	49	1	2	3	24	6	8	5
	D	62	7	6	5	29	1	6	8
Illinois	A	15	-	-	-	2	6	7	-
	B	11	-	-	-	8	1	2	-
	C	4	-	-	-	4	-	-	-
	D	30	5	5	11	9	-	-	-
Virginia	A	298	-	-	-	2	12	284	-
	B	44	-	-	1	5	4	31	3
	C	12	2	-	1	4	-	4	1
	D	22	6	3	1	6	-	2	4
Alabama	A	178	2	1	-	3	12	158	2
	B	14	2	-	-	1	-	8	3
	C	8	-	-	-	1	1	6	-
	D	18	14	-	-	-	1	3	-
Ohio	A	166	-	-	-	10	38	118	-
	B	27	-	1	-	4	12	10	-
	C	4	-	-	-	2	2	-	-
	D	16	8	-	1	6	-	1	-
Tennessee	A	307	-	-	-	1	6	300	-
	B	15	-	-	-	3	1	11	-
	C	13	-	1	-	8	-	4	-
	D	17	3	1	-	10	1	2	-
Utah	A	20	-	-	-	12	5	3	-
	B	4	-	-	-	4	-	-	-
	C	7	1	1	2	3	-	-	-
	D	7	1	-	1	4	-	-	1
Indiana	A	13	-	-	-	1	8	4	-
	B	4	-	-	1	1	1	1	-
	C	2	-	1	-	-	-	1	-
	D	8	1	-	2	4	-	1	-
Colorado	A	103	-	-	-	8	51	44	-
	B	17	-	-	-	6	10	1	-
	C	6	-	-	-	5	1	-	-
	D	4	-	2	-	1	-	1	-
Group I	A	26	-	-	-	5	5	16	-
	B	12	1	-	1	5	-	3	2
	C	9	-	1	-	6	1	1	-
	D	8	1	-	-	4	1	2	-
Group II	A	153	-	-	-	6	29	118	-
	B	20	-	-	-	5	3	12	-
	C	2	-	1	-	1	-	-	-
	D	-	-	-	-	-	-	-	-
Class total	A	2,185	2	4	0	65	358	1,744	12
	B	540	8	8	8	105	81	284	46
	C	226	13	12	11	93	17	57	23
	D	462	115	47	52	152	11	55	30
Totals		3,413	138	71	71	415	467	2,140	111

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.

	C	12	2	-	1	4	-	4	1
	D	22	6	3	1	6	-	2	4
Alabama	A	178	2	1	-	3	12	158	2
	B	14	2	-	-	1	-	8	3
	C	8	-	-	-	1	1	6	-
	D	18	14	-	-	-	1	3	-
Ohio	A	166	-	-	-	10	38	118	-
	B	27	-	1	-	4	12	10	-
	C	4	-	-	-	2	2	-	-
	D	16	8	-	1	6	-	1	-
Tennessee	A	307	-	-	-	1	6	300	-
	B	15	-	-	-	3	1	11	-
	C	13	-	1	-	8	-	4	-
	D	17	3	1	-	10	1	2	-
Utah	A	20	-	-	-	12	5	3	-
	B	4	-	-	-	4	-	-	-
	C	7	1	1	2	3	-	-	-
	D	7	1	-	1	4	-	-	1
Indiana	A	13	-	-	-	1	8	4	-
	B	4	-	-	1	1	1	1	-
	C	2	-	1	-	-	-	1	-
	D	8	1	-	2	4	-	1	-
Colorado	A	103	-	-	-	8	51	44	-
	B	17	-	-	-	6	10	1	-
	C	6	-	-	-	5	1	-	-
	D	4	-	2	-	1	-	1	-
Group I	A	26	-	-	-	5	5	16	-
	B	12	1	-	1	5	-	3	2
	C	9	-	1	-	6	1	1	-
	D	8	1	-	-	4	1	2	-
Group II	A	153	-	-	-	6	29	118	-
	B	20	-	-	-	5	3	12	-
	C	2	-	1	-	1	-	-	-
	D	-	-	-	-	-	-	-	-
Class total	A	2,185	2	4	0	65	358	1,744	12
	B	540	8	8	8	105	81	284	46
	C	226	13	12	11	93	17	57	23
	D	462	115	47	52	152	11	55	30
Totals		3,413	138	71	71	415	467	2,140	111

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.

Discussion of Auxiliary Operations

Ventilation

In relation to dust control, ventilation sweeps dust away from the point where it is produced and thus aids the workmen in that place. Where several operations are being performed on the same split of air, however, this dust may be carried into other places where men are working and expose them to an additional dust hazard. Ventilation has no tendency to allay dust produced during the various mining operations, except to impinge small quantities of airborne dust on damp surfaces contacted by the air currents and to dilute the concentration.

Ventilation practices of the different coal-producing States did not vary greatly, as the national totals for the industry show in table 14. A State-by-State breakdown of ventilation practices is presented in Appendix D.

TABLE 14. - National totals for ventilation practices in bituminous-coal and lignite mines, by mine classes and proximity to the coal face

Ventilation	Class A[1/]		Class B[1/]		Class C[1/]		Class D[1/]		All mines	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
To face	251	11.6	113	20.9	54	23.9	118	25.5	536	15.7
30 feet of face ..	213	9.7	105	19.4	47	20.8	142	30.8	507	14.9
Last open crosscut	1,620	74.1	320	59.3	125	55.3	201	43.5	2,266	66.4
Natural	99	4.5	1	0.2	0	0.0	0	0.0	100	2.9
Auxiliary fans ...	2	0.1	1	0.2	0	0.0	1	0.2	4	0.1
	2,185	100.0	540	100.0	226	100.0	462	100.0	3,413	100.0

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.

In most mines the air was not carried directly to the face; 66 percent of all mines carried the air no farther than the last crosscut. The remaining mines were divided about equally between those carrying the air within not more than 30 feet of the face and those carrying the air directly to the face. More of the larger mines carried air to the faces than smaller mines. The use of blower fans for auxiliary ventilation was restricted to a few class A and B mines in Pennsylvania and class A and D mines in Virginia.

Wetting Agents

Not many installations were reported in which wetting agents were used. Seventeen mines used wetting agents, and the majority of these added it to spray water at underground dumps or in the tipple, and these sprays were reported to be very effective in preventing clouds of airborne dust from forming. Only 4 mines used wetting agents on face equipment - 3 on continuous-type mining machines and 1 on a conventional loading machine.

Wetting agents added to water lower the interfacial tension and allow the water to spread on the surface of the coal particles being sprayed. Once these particles are wetted, they adhere to larger pieces of coal and are prevented from becoming airborne. Water with a wetting agent will therefore wet more coal with less water, because the water will spread evenly over the coal surfaces and not lie in puddles on top of a mass of dry coal.

Employment of Dust-Control Engineers and Surveys of Airborne Dust

Dust-control engineers were employed in 21 mines; 5 of these mines were in southern West Virginia, 5 in Kentucky, 6 in Alabama, 2 in Colorado, and 1 each in Illinois, Pennsylvania, and Oklahoma. All these men were employed in class D mines, except for one class B mine in Kentucky. Dust surveys have been made in virtually all the mines employing dust-control engineers, and six additional mines had surveys made but did not employ engineers for that purpose.

These surveys probably were made by consultants, the Bureau of Mines, or other governmental agencies.

CONCLUSIONS

Results of the survey indicated that the larger mines seemed the most dust-conscious, whereas most of the smaller mines appeared to pay little or no attention to the dust problem or to have concluded, in the case of wet mines, that no such problem could exist.

Water was the chief agent used to prevent the dissemination of dust and in efforts to allay dust that had become airborne. Water was not always entirely effective in controlling the dust produced in the various operations on which it was used but usually had some beneficial results. Few mines added wetting agents to the water. Dry dust collectors were employed mainly in connection with roof drilling for roof bolting. The deeper, drier mines present the greater problems in respect to dust, and it was in these mines that the greatest use of control measures was found.

The survey showed clearly that, even though much had been done by a considerable segment of the coal-mining industry to prevent the formation of high concentrations of airborne dust, a great deal remained to be done in this direction. The need for more and better control measures was obvious. More study should be devoted to effective application of water as a suppressive measure, the design, location, and efficiency of spray nozzles, and the coursing of ventilation through areas where dust is generated. It is believed also that manufacturers of mining equipment should consider means for dust control as a necessary and integral part of the design of the equipment.

Better application of the existing systems for dust control also was a need, as the survey showed that the controls used were, on the whole, effective in only about 50 percent of the applications, as judged by visual observation of dust dissemination. Programs for controlling dust will be effective only if all concerned are dust-conscious, from top management down through the ranks, so that all efforts are coordinated to accomplish the desired and necessary results. Realization of the fact that inhalation of high concentrations of any airborne mine dust is likely to be harmful is bringing about increased use of dust-control measures, which may be expected to offset their cost by improved health and safety of employees, greater efficiency, and better labor-management relations.

The survey showed that the necessity for dust control is being recognized in the coal-mining industry but that improved measures of suppression are needed in many instances and that the problem should be attacked in broader scope.

APPENDIX

A: List of States according to daily production at time of survey

	State	Daily tonnage
1.	West Virginia	526,482
2.	Pennsylvania	317,000
3.	Kentucky	226,214
4.	Illinois	156,788
5.	Virginia	80,471
6.	Alabama	69,023
7.	Ohio	60,536
8.	Tennessee	37,569
9.	Utah	29,767
10.	Indiana	27,988
11.	Colorado	19,541
12.	Group I	17,586
13.	Group II	7,748
	Total	1,576,713

B: List of States covered by survey, showing total number of mines, total employment, and daily production in each size class

State	Class 1/	Mines	Employment	Daily tonnage	State	Class 1/	Mines	Employment	Daily tonnage
West Virginia (Northern)	A	171	1,346	9,737	Ohio	A	166	1,152	6,661
	B	79	2,096	24,410		B	27	678	4,950
	C	18	1,202	14,460		C	4	269	2,215
	D	27	7,018	96,539		D	16	4,062	46,710
	Total	295	11,662	145,146		Total	213	6,161	60,536
West Virginia (Southern)	A	39	313	2,657	Tennessee	A	305	1,713	7,692
	B	76	2,322	24,084		B	15	393	3,220
	C	61	4,607	55,590		C	13	933	9,325
	D	148	35,355	299,005		D	17	2,806	17,332
	Total	324	42,597	381,336		Total	350	5,845	37,569
Pennsylvania	A	280	1,821	11,241	Utah	A	20	128	2,617
	B	103	2,742	19,448		B	4	86	1,650
	C	31	2,332	20,128		C	7	541	7,150
	D	95	34,825	266,183		D	7	1,857	18,350
	Total	509	41,720	317,000		Total	38	2,612	29,767
Kentucky	A	416	2,803	20,511	Indiana	A	13	114	973
	B	114	3,160	29,565		B	4	110	1,405
	C	49	3,345	36,605		C	2	116	1,481
	D	62	13,955	139,533		D	8	1,725	24,129
	Total	641	23,263	226,214		Total	27	2,065	27,988
Illinois	A	15	160	1,540	Colorado	A	103	383	2,472
	B	11	314	2,925		B	17	424	4,689
	C	4	272	4,400		C	6	447	4,730
	D	30	8,710	147,923		D	4	1,242	7,650
	Total	60	9,456	156,788		Total	130	2,496	19,541
Virginia	A	298	2,362	18,828	Group I	A	26	114	608
	B	44	1,124	10,225		B	12	356	2,637
	C	12	789	7,428		C	9	694	4,466
	D	22	5,607	43,990		D	8	1,308	9,875
	Total	376	9,882	80,471		Total	55	2,472	17,586
Alabama	A	178	1,032	6,043	Group II	A	153	857	3,777
	B	14	361	3,055		B	20	521	2,705
	C	8	553	3,340		C	2	147	1,266
	D	18	5,196	56,585		D	-	-	-
	Total	218	7,142	69,023		Total	175	1,525	7,748

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.

C: Roof-bolting practices. Roof bolting by State production, showing number of mines according to employment groups and percentage of coal produced from roof-bolted areas

State	Mines: Class1/	Mines: Number	Extent of roof-bolting practices: Total mines bolting	Spot bolting	Experi-mental bolting	Production from roof-bolted areas, percent: 0-49	50-99	100
West Virginia (Northern)	A	171	-	-	-	-	-	-
	B	79	11	-	3	-	-	8
	C	18	5	-	-	2	-	3
	D	27	17	-	-	4	6	7
West Virginia (Southern)	A	39	-	-	-	-	-	-
	B	76	8	3	-	2	-	3
	C	61	19	3	-	6	3	7
	D	148	76	11	1	22	23	19
Pennsylvania	A	280	1	-	1	-	-	-
	B	103	4	2	1	-	1	-
	C	31	5	-	-	1	3	1
	D	95	46	1	4	16	18	7
Kentucky	A	416	1	-	-	-	-	1
	B	114	13	3	-	1	1	8
	C	49	12	6	1	3	-	2
	D	62	39	11	3	13	3	9
Illinois	A	15	2	1	-	1	-	-
	B	11	2	-	-	-	-	2
	C	4	3	-	-	-	1	2
	D	30	18	4	-	4	5	5
Virginia	A	298	-	-	-	-	-	-
	B	44	4	2	-	-	-	2
	C	12	4	-	-	-	3	1
	D	22	15	5	2	5	1	2
Alabama	A	178	2	1	-	1	-	-
	B	14	2	-	-	-	-	2
	C	8	2	1	-	-	1	-
	D	18	13	-	-	6	2	5
Ohio	A	166	3	-	1	-	2	-
	B	27	-	-	-	-	-	-
	C	4	-	-	-	-	-	-
	D	16	6	-	1	3	2	-

State	Mines: Class1/	Mines: Number	Extent of roof-bolting practices: Total mines bolting	Spot bolting	Experi-mental bolting	Production from roof-bolted areas, percent: 0-49	50-99	100
Tennessee	A	307	1	-	-	-	-	1
	B	15	1	-	1	-	-	-
	C	13	7	-	2	-	3	2
	D	17	1	-	-	-	1	-
Utah	A	20	1	-	-	-	1	-
	B	4	-	-	-	-	-	-
	C	7	3	1	1	-	-	1
	D	7	5	1	-	1	2	1
Indiana	A	13	1	-	1	-	-	-
	B	4	1	1	-	-	-	-
	C	2	2	1	-	-	-	1
	D	8	7	1	-	1	2	3
Colorado	A	103						
	B	17						
	C	6			NONE			
	D	4						
Group I	A	26	-	-	-	-	-	-
	B	12	-	-	-	-	-	-
	C	9	2	1	-	-	-	1
	D	8	2	-	-	2	-	-
Group II	A	153	1	-	1	-	-	-
	B	20	-	-	-	-	-	-
	C	2	2	1	-	-	1	-
	D	-	-	-	-	-	-	-
National total	A	2,185	13	2	4	2	3	2
	B	540	46	11	5	3	2	25
	C	226	66	14	4	12	15	21
	D	462	245	34	11	77	65	58
	Total	3,413	370	61	24	94	85	106

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.

D: Ventilation practices

State	Mines: Class1/	Mines: Number	Ventilation carried to-: Face	Ventilation carried to-: 30 feet of face	Ventilation carried to-: Last crosscut	Natural ventilation
West Virginia (Northern)	A	171	13	35	123	-
	B	79	7	15	57	-
	C	18	3	3	12	-
	D	27	9	6	12	-
West Virginia (Southern)	A	39	8	16	15	-
	B	76	32	16	28	-
	C	61	32	3	26	-
	D	148	65	38	45	-
Pennsylvania	A	280	27	14	210	28
	B	103	28	29	45	-
	C	31	2	16	13	-
	D	95	14	54	27	-
Kentucky	A	416	2	12	377	25
	B	114	3	4	107	-
	C	49	3	3	43	-
	D	62	7	10	45	-
Illinois	A	15	-	-	15	-
	B	11	-	1	10	-
	C	4	-	-	4	-
	D	30	2	3	25	-
Virginia	A	298	2	3	290	2
	B	44	6	1	37	-
	C	12	3	3	6	-
	D	22	4	4	13	-
Alabama	A	178	74	23	61	20
	B	14	4	10	-	-
	C	8	1	5	2	-
	D	18	8	9	1	-
Ohio	A	166	6	3	154	3
	B	27	7	2	18	-
	C	4	-	-	4	-
	D	16	1	1	14	-

State	Mines: Class1/	Mines: Number	Ventilation carried to-: Face	Ventilation carried to-: 30 feet of face	Ventilation carried to-: Last crosscut	Natural ventilation
Tennessee	A	307	-	22	271	14
	B	15	-	4	10	1
	C	13	-	-	13	-
	D	17	-	6	11	-
Utah	A	20	1	17	1	1
	B	4	-	3	1	-
	C	7	-	7	-	-
	D	7	-	7	-	-
Indiana	A	13	-	4	9	-
	B	4	-	-	4	-
	C	2	-	-	2	-
	D	8	-	-	8	-
Colorado	A	103	47	21	23	2
	B	17	9	6	2	-
	C	6	2	4	-	-
	D	4	4	-	-	-
Group I	A	26	14	8	4	-
	B	12	5	7	-	-
	C	9	6	3	-	-
	D	8	4	4	-	-
Group II	A	153	47	35	67	4
	B	20	12	7	1	-
	C	2	2	-	-	-
	D	-	-	-	-	-
National total	A	2,185	241	213	162	99
	B	540	113	105	320	1
	C	226	54	47	125	-
	D	462	118	142	201	-

Note: Auxiliary fans are used in 2 mines (class A and B) in Pennsylvania; 2 mines (class A and D) in Virginia.

1/ Mine classes: A = 1-14 men underground, B = 15-49, C = 50-99, D = 100 or more.

E: Questionnaire used in survey

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

SURVEY OF DUST-CONTROL PRACTICES
IN THE COAL MINING INDUSTRY

Inspector's name ______________________ Date ____________

Name of mine and operating company ______________________

____

Location of mine--
State ______________ County ________ Town ________

Number of men employed--
Underground ______________________

Surface (tipple and cleaning plants only) ____________

Number of shifts per day ______________________

Average production, tons per day ______________________

Coal bed, name and height in inches ______________________

In the following questions on operations, the intent is to obtain information on type of operation and equipment, whether or not dust-control measures are provided, whether they appear effective, and in all cases whether visible dust is evident in the working area of the men engaged in the operation. Check marks, or YES or NO, will suffice to answer many of the questions.

DRILLING

	Coal face	Roof	Bottom	Draw slate
Rotary?	______	____	_____	______
Percussion?	______	____	_____	______
Wet?	______	____	_____	______

DRILLING (con.)

	Coal face	Roof	Bottom	Draw slate
Dry?	______	______	______	______
Dust-collector?	______	______	______	______
Visible dust?	______	______	______	______

To what extent is roof bolting practiced? ______________________

____

____

COAL CUTTING

	Bottom	Top	Shear
Water on cutterbar?	______	______	______
Sprays?	______	______	______
Jets?	______	______	______
Other?	______	______	______
During sumping in?	______	______	______
Visible dust?	______	______	______

BLASTING

On shift or off shift? ______________________________

By shotfirers or by other workmen? ______________________

	Conventional permissible	Airdox	Cardox	Chemecol	Other
Place wet before blasting?	______	______	______	______	______
Place ventilated before men return?	______	______	______	______	______

BLASTING (con.)

	Conventional permissible	Airdox	Cardox	Chemecol	Other
Material wetted after blasting ?	_____	_____	_____	_____	_____
Visible dust and smoke when men return?	_____	_____	_____	_____	_____

LOADING

	Hand	Mechanical	Type or make of loader, if mechanical
Material wetted before or while loading	_____	_____	______________
Visible dust?	_____	_____	______________

CONTINUOUS MINING-TYPE MACHINES

No dust control? ____

Dust control by ventilation? __________________________________

Brattice to face? ____

Dust control by wetting? _____________________________________

Visible dust? ____

Describe dust control method briefly. ___________________________

____

____

____

____

____

TRANSPORTATION

	Conventional cars	Shuttle car	Conveyor (type)
Coal wetted before or during transportation?	________	________	________
Cars dust-tight?	________	________	________
Cars overloaded?	________	________	________
Dust suppresion at transfer or dumping points?	________	________	________
Visible dust?	________	________	________
If above answer YES, at what points in transport?	________	________	________

HAULAGEWAYS

Are haulageways cleaned up, wetted, or treated with salt, calcium chloride, or other consolidating agent? ______________________________

____

VENTILATION

How close to face operation is ventilation carried? ________________

____

WETTING AGENTS

Are wetting agents used underground? ______________________

If so, in what operations? ______________________

Brand of wetting agent? ______________________

Considered effective by management? ______________________

TIPPLE AND CLEANING PLANT

Give brief description of dust-control practices, covering dump, screens, crusher, and loading booms, mentioning whether wet methods, exhaust hoods, and dust collectors are used. ________________________________

____

____

____

At what points is dust visible? ____________________________________

____

____

Disposal of settled dust? ____

____

DOES COMPANY HAVE DEFINITE PROGRAM FOR DUST CONTROL?

Employ dust-control engineer? ____________________________________

Are surveys of air-borne dust made? _______________________________

ATTITUDE OF MINERS TOWARD PRACTICE OF DUST CONTROL

Are men cooperative in using dust-control measures provided? __________

____

ADDITIONAL REMARKS. Add anything else considered pertinent to the problem of dust control. If any unusual or unique dust-control methods or equipment are in use, describe briefly. ______________________________

____

____

____

Use additional sheets if necessary.

Bureau of Mines
Information Circular 7734

ADMINISTRATION OF THE FEDERAL COAL-MINE SAFETY ACT, CALENDAR YEAR 1954

BY JAMES WESTFIELD, H. F. WEAVER, AND C. M. KEENAN

United States Department of the Interior — February 1956

ADMINISTRATION OF THE FEDERAL COAL-MINE SAFETY ACT, CALENDAR YEAR 1954

BY JAMES WESTFIELD, H. F. WEAVER, AND C. M. KEENAN

* * * * * * * * * Information Circular 7734

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
Thos. H. Miller, Acting Director

February 1956

FOREWORD

This report presents in full the Annual Report of the Division of Coal-Mine Inspection, Bureau of Mines, for the calendar year 1954, prepared and transmitted to the Congress by the Secretary of the Interior pursuant to the requirements of the Federal Coal Mine Safety Act.

During 1953, the first full year of operation under the act, the coal-mining industry enjoyed the best accident record in its statistical history. It is believed that the report reproduced herein contains pertinent information of sufficient importance to present as an information circular and be made a permanent record as a Bureau publication.

ADMINISTRATION OF THE FEDERAL COAL-MINE SAFETY ACT, CALENDAR YEAR 1954

by

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INTRODUCTION

This report covers the calendar year 1954 and has been prepared and submitted to the Congress of the United States in accordance with the provisions of Sec. 106(a) and Sec. 212(c) of the Federal Coal-Mine Safety Act (66 Stat. 692; 30 U.S.C. Sec. 451-483).

Background

The Federal Coal-Mine Inspection program was established to carry out the provisions of Public Law 49, 77th Congress, H. R. 2082, approved May 7, 1941. This act has since been amended to be known as Title I - Advisory Powers Relating to Health and Safety Conditions in Mines, under Public Law 552, 82d Congress, approved July 16, 1952, which also includes Title II - Prevention of Major Disasters in Mines. Public Law 552 is known as the Federal Coal-Mine Safety Act.

The Congress passed this act as a result of public indignation and the demands for enforcement powers for Federal coal-mine inspectors after a series of seven appalling major coal-mine disasters that occurred between January 18, 1951, and March 27, 1952. One of these, an explosion in the Orient No. 2 mine, Chicago, Wilmington,& Franklin Coal Co., Ill., on December 21, 1951, caused the death of 119 men.

Under the provisions of Title I, the Secretary of the Interior, acting through the Federal Bureau of Mines, is authorized and empowered to make, or cause to be made, annual or necessary inspections and investigations in coal mines, the products of which regularly enter commerce or the operations of which substantially affect commerce. The principal functions of the Federal coal-mine inspectors under Title I are to determine the causes of accidents and occupational diseases in coal mines and then endeavor to eliminate or ameliorate them (1) by revealing, through personal conferences with mine personnel, correspondence, and published reports, the unhealthful and unsafe conditions and practices existing in the mines and (2) by recommending practical means for correcting the conditions observed. Title I does not provide any enforcement powers, and therefore compliance with the inspectors' recommendations under its provisions is not mandatory; it does give Federal coal-mine inspectors the right to enter coal mines for inspection.

Title I further authorizes and directs the Secretary of the Interior, acting through the Bureau of Mines, to expend the funds made available to him for advancing health and safety in coal mines and preventing or relieving accidents or occupational diseases therein in such lawful manner as he may deem most effective in the light of the information obtained to accomplish the objects for which such funds are granted. To comply with such directive the Division of Coal-Mine Inspection personnel is conducting nationwide safety-education programs for coal-mine officials and coal-mine workmen. In addition, special studies are made of mine health and safety problems relating to roof control, haulage, ventilation, mine disasters, dusts, explosives, gases, electricity, etc.; the results of such

studies and any improved methods determined from them are made available to the mining industry and general public through published reports.

The current National Bituminous-Coal Wage Agreement between the United Mine Workers of America and Bituminous-Coal Operators provides in part as follows:

(a) Mine Safety Code.

The Federal Mine Safety Code for Bituminous Coal and Lignite Mines of the United States, adopted pursuant to an agreement dated May 29, 1946, between the Secretary of the Interior and the President of the United Mine Workers of America and promulgated July 24, 1946, is hereby adopted and incorporated by reference in this contract as a code for health and safety in bituminous-coal and lignite mines ---.

(b) Enforcement.

(1) Reports of Federal Coal-Mine Inspectors:- Wherever inspectors of the Federal Bureau of Mines, in making their inspections in accordance with authority as provided in Public Law 49, 77th Congress, find that there are violations of this code and make recommendations for the elimination of such noncompliance, the Operator shall promptly comply with such recommendations, except as modified in paragraph two of the subdivision (b).

(2) Whenever either party to the contract feels that compliance with the recommendations of the Federal mine inspectors as provided above would cause irreparable damage or great injustice, they may appeal such recommendation to the Joint Board of Review as hereinafter provided.

The current Anthracite Wage Agreement between the United Mine Workers of America and Anthracite operators provides in part as follows:

Mine Safety Program.

(a) Federal Mine Safety Standards.

Inspectors of the Federal Bureau of Mines shall make periodic investigations of the mines, and report to the mine management and the United Mine Workers of America any violations of the Federal Safety Standards.

Operators and Mine Workers agree to accept such standards of safety adaptable and practical to the anthracite industry, subject, however, to the right of review by the Director of the Federal Bureau of Mines, upon petition from the Operator or the United Mine Workers of America.

The Federal Mine Safety Code for Bituminous-Coal and Lignite Mines of the United States and the Safety Standards for Anthracite Mines (now the Federal Mine Safety Code for Anthracite Mines of the United States) have been used as the bases for citing substandard conditions in bituminous-coal and anthracite mines, respectively.

Title II of the Federal Coal-Mine Safety Act is designed to prevent major disasters in mines the products of which regularly enter interstate or foreign commerce or the operations of which substantially affect such commerce, and compliance with its safety provisions is mandatory. However, it applies only to coal mines in which 15 or more individuals are employed regularly underground. To accomplish this, Title II requires that the Director of the Bureau of Mines shall cause an inspection of each such mine to be made at least annually to determine whether an imminent danger described in Sec. 203(a) exists in any such mine or any provision of the Mine Safety Provisions of Sec. 209 is being violated in any such mine or whether any such mine is a gassy mine as prescribed in Sec. 203(d). It further provides that the Director shall make or cause to be made such special inspections of such mines as may be required by Sec. 203(c) and Sec. 206, and such other inspections of such mines as he deems necessary for the proper administration of Title II. Provisions have also been made for joint inspections of mines with representatives of the inspection agency of any State that desires to cooperate and submits a suitable plan for participation.

The Advisory Committee

Section 108 of Title I provides for the appointment of an Advisory Committee composed of not more than six members to exercise consultative functions when required by the Secretary of the Interior in connection with the administration of Title I. The following persons constitute the present members of the Committee:

Thomas Kennedy, vice president, United Mine Workers of America, Washington, D. C.

W. A. Boyle, assistant to the president, United Mine Workers of America, Washington, D. C.

John T. Jones, president, District 16, United Mine Workers of America, Washington, D. C.

L. C. Campbell, vice president, Eastern Gas & Fuel Associates, Coal Division, Pittsburgh, Pa.

Harry Treadwell, vice president, Chicago, Wilmington, & Franklin Coal Co., Chicago, Ill. (Retired June 1954)

E. C. Weichel, vice president, The Hudson Coal Co., Scranton, Pa.

Meetings of the committee have been held:

Sept. 3, 1941, at Washington, D. C.
Dec. 3, 1941, at Pittsburgh, Pa.
May 12, 1942, at Washington, D. C.
Nov. 5, 1942, at Washington, D. C.
Jan. 28, 1946, at Washington, D. C.
Oct. 3, 1950, at Washington, D. C.

SUMMARY

Following is a brief résumé of some of the most recent activities of the Division of Coal-Mine Inspection that have had a favorable effect on health, safety, and reduction of injuries at coal mines:

1. There were approximately 8,360 active coal mines in the United States during 1954. In all, 72,566 regular Federal inspections of coal mines have been made since Public Law 49 became effective in May 1941; 10,519 of these inspections were made during 1954.

2. The Bureau of Mines introduced the revised Coal-Mine Accident-Prevention Course for Supervisors into the coal-mining industry on March 1, 1948; since that date 19,310 supervisors and those aspiring to official positions have completed such training conducted by personnel of the Division of Coal-Mine Inspection.

3. The Bureau of Mines introduced the revised Coal-Mine Accident-Prevention Course for Miners in the coal-mining industry on January 1, 1947; since that date 107,690 mine workers have completed such training, including 3,183 in special on-the-job classes conducted by Division of Coal-Mine Inspection personnel assigned temporarily to educational work. In addition, thousands of mine workers have been given specialized training in the maintenance, use, and limitations of permissible flame safety lamps to qualify them to make tests for gas according to the provisions of Sec. 209(d)(9) of the Federal Coal-Mine Safety Act.

4. The Bureau of Mines introduced a short Coal-Mine Haulage Safety Course in the coal-mining industry on April 1, 1951; subsequent to that date 122,170 haulage employees and others completed such training conducted by Federal coal-mine inspectors.

5. The Bureau of Mines initiated a short Coal-Mine Roof-Control Course, designed to impress upon mine officials and workmen the need for more adequate roof-control measures and to make all concerned more roof-control-conscious, on May 1, 1951. This course is very popular and to date has been completed by 218,277 persons.

6. Organizational work to extend the benefits of The Holmes Safety Association is meeting with enthusiastic support from the States, mine operators, and mine workers.

7. The Federal Mine Safety Code for Bituminous-Coal and Lignite Mines of the United States was originally issued by the Director of the Bureau of Mines on July 24, 1946, after consultation with management and labor representatives of the coal-mining industry. The code has been used by Federal coal-mine inspectors during their inspections of bituminous-coal and lignite mines as a basis for determining the existence of unhealthful and unsafe conditions and practices in these mines. A revised code was issued by the Secretary of the Interior on October 8, 1953, following further consultations with representatives of management and mine workers. The agreement of May 29, 1946, between the Secretary of the Interior, acting as Coal-Mines Administrator under authority of Executive Order 9728, and the United Mine Workers of America covering bituminous-coal and lignite mines in Government possession, charged Federal coal-mine inspectors with the responsibility of making periodic investigations of the mines and reporting to the Coal-Mines Administrator any violations of the Federal Mine Safety Code. These inspectors were active in making prompt investigations of hazardous mines that had been closed

by order of the Coal-Mines Administrator to determine whether enough improvements had been made to allow the mines to reopen. Federal coal-mine inspectors also had temporary authority to close mines they found to be imminently dangerous, but such authority under Executive Order 9728 was removed on June 30, 1947, when Government control of the mines was terminated.

8. The Safety Standards for Anthracite Mines were prepared by personnel of the Bureau of Mines and have been used by Federal coal-mine inspectors as a basis for determining unhealthful and unsafe conditions and practices during their inspections of the anthracite mines of Pennsylvania. These standards were also revised and issued by the Secretary of the Interior as the Federal Mine Safety Code for Anthracite Mines of the United States on October 14, 1953.

9. Public Law 328 - 80th Congress, Chapter 450 - 1st Session, effective for 1 year following its approval on August 4, 1947, required the Secretary of the Interior, acting through the Director of the Bureau of Mines, to submit quarterly reports to the Congress of the United States with respect to the conditions of all bituminous-coal and lignite mines inspected by Federal coal-mine inspectors, all recommendations and notifications sent to the State agencies, and action taken by such mine owners, operators, and the State agencies with respect to his findings and recommendations.

10. Introduction of the bolting method of roof control to the coal-mining industry by the Bureau of Mines in 1948 is a major contribution toward reducing coal-mine accidents. The success of this new method of roof control shows that it is likely to surpass the use of rock dust as a means of preventing loss of life and serious injuries in coal mines. Certain mining engineers and coal-mine inspectors have been especially trained in mine-roof control and roof bolting, and they inform mine operators whether bolting is practical in their mines and, if so, the proper plan of bolting to follow.

11. To further intensify the attack on roof-fall injuries, a program of research and investigation by Bureau of Mines engineers was established in 1953 to develop mobile or portable devices for use at working faces to protect workmen in these areas where most roof-fall accidents occur. The Bureau is also doing the spadework and keynoting on an intensive, cooperative, nationwide campaign to prevent roof-fall injuries, which was organized late in 1954.

12. The advent of roof bolting brought with it a health hazard from dusts produced during drilling in roof rock. The Bureau has been active in eliminating this hazard by cooperating with manufacturers of mining equipment in designing permissible dust collectors that may be used in lieu of water to allay the dust at its source. Bureau of Mines Schedule 25, Procedure for Testing Dust Collections for Permissibility for Use in Connection With Rock Drilling in Coal Mines, became effective January 23, 1952, and was later amended July 23, 1952. Numerous dust collectors have met these requirements and have been approved for use in coal mines under Schedule 25.

13. Federal coal-mine inspectors began investigating all coal-mine fatalities on February 10, 1950. The reports of these investigations are made available to the industry, and the information in them is summarized and published annually with the hope that it will be helpful in preventing accidents in coal mines.

14. On October 2, 1953, a program was inaugurated to have personnel engaged in coal-mine inspection collect detailed information on dust conditions and dust-control

practices in each coal mine inspected to assist the chief, Branch of Health Research, in assembling such information to determine the extent that occupational disease hazards exist in the Nation's mines as a result of exposure of workmen to dust-laden atmospheres. This program has been completed, and a report thereon is being prepared.

15. Other special studies covering roof control, explosives, gases (including re-storage of natural gas beneath coal measures), fires, explosions, mining, electricity, haulage, ventilation, and control of atmospheric dusts are being made continually as part of the health and safety program set up under the Federal Coal Mine Safety Act. Reports of findings and recommendations are made available to the coal-mining industry.

16. Since 1947, personnel of the Bureau of Mines has assisted in preparing proposed revisions of the coal-mining laws of 12 States. The Bureau of Mines will continue to furnish this service to any agencies directly concerned with improving State mining laws, such as labor organizations, coal-operators' associations, and State officials.

17. In response to letters from the Secretary of the Interior to the Governors of coal-producing States and personal contacts by field personnel, State-participation plans for joint State-Federal coal-mine inspections, as provided for under Sec. 202(b) of Title II, Federal Coal Mine Safety Act, have been approved and are in effect in Alaska, North Carolina, North Dakota, Oklahoma, Washington, and Wyoming.

18. Members of the Division of Coal-Mine Inspection take an active part in national, regional, and local safety organizations throughout the coal-mining areas.

19. Coal-mine inspectors and engineers of the division have served on foreign duty in response to requests from other Federal agencies. This provides such agencies with the technical knowledge and wide experience of these experts, and the assignees have the opportunity to add to their fund of knowledge and make pertinent information available to the mining industry in this country.

20. The Division of Coal-Mine Inspection has entered into a cooperative agreement with the Wage and Hour and Public Contracts Divisions of the U. S. Department of Labor, whereby the Bureau of Mines field office promptly notifies the regional office of the Wage and Hour and Public Contracts Divisions of disaster hazards in mines that are not covered by the mandatory provisions of Title II but are under contract to furnish coal to the Federal Government. The operators of such mines face cancellation of Government contracts if the hazards are not eliminated promptly.

The health and safety conditions in coal mines in the United States have been improving steadily since Federal coal-mine inspections were instituted. However, the frequency of roof-fall fatalities and minor mine fires and gas or dust ignitions indicates that much remains to be done before the conditions in many mines can be considered even fairly satisfactory.

The enactment of the Federal Coal Mine Safety Act, July 16, 1952, affords under Title II limited enforcement powers to the Federal coal-mine inspectors with respect to certain safety provisions that might cause or lead up to a major disaster in underground mines that regularly employ 15 or more men underground. However, the act is not designed to and prescribes no mandatory provisions to prevent the so-called day-to-day accidents that result in over 90 percent of the coal-mine fatalities or

to prevent accidents in mines that employ regularly less than 15 men underground, which, as a group, usually have high accident-frequency rates. This large field is left to cooperative efforts among the Federal Bureau of Mines, the State agencies, employers, and employees. The enforcement of rules and regulations in the field of day-to-day accidents, safety, health, and welfare is clearly left within the jurisdiction of the several States.

There is no doubt that much more can be accomplished if the mandatory safety provisions of the act are extended to cover mines that employ regularly less than 15 individuals underground, which, as a group, are poorly regulated. This is borne out by the fact that 39 percent of the inspection reports on these mines indicated dangers of a serious nature that were not corrected promptly, and only 16 percent of all the dangerous conditions reported were being corrected during the period covered by this report. Also, the frequency rate for underground fatalities at Title I mines in 1954 was 4.22 as compared with a frequency of 1.01 for underground fatalities at Title II mines.

EMPLOYMENT OF PERSONNEL

Coal-mine inspectors, electrical inspectors, and engineers of the Division of Coal-Mine Inspection are selected from the Civil Service register, and applicants must meet the rigid requirements set up by the United States Civil Service Commission before their names can be included in the register. On July 19, 1954, the register was closed against the acceptance of additional applications.

The current requirements for the several grades of Federal coal-mine inspectors are as follows:

United States Civil Service Commission Requirements for Federal Coal-Mine Inspectors

Written Description of Some Phase of Coal Mining

Applicants must submit with their application a 300-word description of some phase of coal mining, such as the ventilating system, haulage system, or timbering methods used in a mine familiar to the applicant. The applicant must prepare the description, and he must certify in his own handwriting that he received no assistance in composing it. Applicants who fail to submit this written description, or who submit an unsatisfactory one, or who submit statements copied from texts or other sources of which they are not the authors, will receive no further consideration under this announcement.

Experience

Applicants must show, as a mininum, the quality and amount of experience prescribed hereafter, unless they substitute education for experience (see Substitution of Education for Experience following). To establish eligibility in any grade, at least 1 year of the required experience for that grade must have been acquired during the 4 years immediately preceding the date of filing application.

GS-9, $5,060 - Six years of progressive experience in practical coal mining, of which at least 2 years must have been specialized experience in coal-mining operations of medium size that involved responsibility for providing adequate modern safety and health programs in a position of at least the responsibility required of a mine superintendent, mine foreman, mining engineer, or safety

inspector. The nature of the experience must have been broader than that of a fire boss, mine examiner, or section foreman and must have demonstrated the ability to perform important coal-mine inspection work under general supervision.

GS-11, $5,940 - Seven years of progressive coal-mining experience, of which 3 or more years must have been specialized experience that required supervision of difficult, important, and responsible work subject only to general supervision and review in a position of at least the responsibility required of a mine superintendent, mine foreman, mining engineer, or safety engineer. The experience must have included the direction, application, and enforcement of modern coal-mine safety and health programs. This experience must also have demonstrated that the applicant has (1) a thorough knowledge of the basic principles applicable to modern programs for promotion of safety and health in coal mines; (2) the resourcefulness, initiative, and ability to perform, direct, and coordinate moderately large scale mine-inspection work of considerable difficulty; and (3) administrative ability, tact, and judgment necessary to promote programs for improved safety, health, and working conditions in coal mines and in applying mine safety regulations.

GS-12, $7,040 - Eight years of progressive experience in the various operations necessary in development and production in coal mines, including at least 4 years of difficult, important, and responsible specialized work that was subject to only a general administrative supervision in a capacity such as direct supervisor. This work must have included full responsibility for directing and applying modern coal-mine safety and health programs. This experience must have demonstrated that the applicant has (1) a thorough knowledge of the basic principles applicable in modern programs for promoting health and safety in coal mines; (2) the resourcefulness, initiative, and ability required in a position of at least the responsibility of mine manager, mine superintendent, mining engineer, or safety engineer; (3) the ability to perform, direct, and coordinate large-scale mine-inspection work of unusual difficulty; and (4) administrative ability of a high order, along with the tact and judgment necessary to administer safety regulations and to conduct important conferences with interested parties, such as coal-mine operators, labor organizations, and the general public, on matters related to safety and health of workers engaged in coal mining.

Provisions of Law

Section 109 of the Federal Coal-Mine Safety Act under which these positions are established provides:

> That in the selection of persons for appointment as coal-mine inspectors no person shall be so selected unless he has the basic qualification of at least 5 years practical experience in the mining of coal, and is recognized by the United States Bureau of Mines as having the training or experience of a practical mining engineer in those essentials necessary for competent coal-mine inspection.

The provisions of law quoted above are made a part of the requirements of this examination. Persons whose qualifications are not such as to receive the recognition of the Federal Bureau of Mines as required by law cannot be accorded an eligible rating in this examination. The nature of each applicant's experience and the required degree of ability will be carefully determined before eligibility and rating are decided. Experience will be evaluated on the type, size, and difficulty of operation in mines in which the applicant has had supervisory responsibility.

Substitution of Education for Experience

A successfully completed course of study in engineering at an accredited college or university may be substituted for part of the required general experience on the basis of 1 year of education for 6 months of experience. Such substitution will be limited to 1 year of required general experience in GS-9 grade and to 2 years of required general experience in the GS-11 and GS-12 grades. In each instance, however, the applicant must show the total required amount of specialized experience.

The successful completion of college work in nonaccredited institutions will be accepted on the same basis as indicated for accredited colleges under the requirements for the position, provided that such institutions give instruction of definitely collegiate level and that the State university of the State in which the institution is situated accepts the courses and gives advanced credit for them. (In those States where there is no State university, the evaluation and acceptance of college credits as made by the State department of education will be accepted.)

Ability to Drive Automobiles

Applicants must give evidence that they can operate automobiles. Possession of a valid automobile operator's license in the State of legal residence of an applicant will be accepted as evidence.

Citizenship

Applicants must be citizens of or owe allegiance to the United States.

Age

Applicants must not have passed their 48th birthday on the date of filing application.

Physical Abilities

Applicants must be physically capable of performing efficiently the arduous duties of this position. They must be free of such defects or diseases as may constitute an employment hazard to themselves or endanger fellow employees or others. They must be capable of sustained physical exertion for 6 to 8 hours per day under such hazardous conditions as traveling over rock falls, on steep pitches, in adverse atmospheric conditions, and under low roof where it is frequently necessary to crawl on the hands and knees. Inspectors entering a mine to make an inspection normally carry equipment weighing up to 20 pounds. In emergencies following a mine disaster, they may be required to work for several 2-hour periods a day carrying rescue apparatus, which weighs about 40 pounds. Arms and legs must be sufficiently intact and functioning to permit the applicant to perform the duties described above. Vision must be at least 20/50 Snellen in one eye and 20/70 in the other, without glasses. The ability to distinguish basic color is essential. Hearing, with or without a hearing aid, must be acute enough to enable the applicant to hear ordinary conversation at 20 feet. These standards must be met by all applicants; however, certain requirements may be waived for veterans who can demonstrate ability to perform the duties efficiently and safely.

In view of the strenuous physical exertion required for this position, hernia (whether or not supported by truss), organic heart disease (whether or not

compensated), varicose veins (unless slight), serious deformities or disabilities of extremities (including weak feet), mental or nervous disease, chronic respiratory or chronic constitutional disease, or other physical defect that would cause the applicant to be a hazard to himself or others or would prevent efficient performance of the duties of the position will disqualify him for appointment.

Applicants will be required to submit a certificate of physical examination upon request, and a check physical examination will be made by a Federal medical officer before the oath of office will be administered at the first post of duty. Persons who are offered appointment must pay their own expenses in reporting for duty. If, upon reporting at the place of assignment, they are found to be ineligible because of physical defects, they cannot be appointed, and no part of their expenses in returning home can be paid by the Government.

Basis of Ratings

No written test is required. Applicants' qualifications will be rated on a scale of 100 and will be judged from a review of their experience, education, and training and on corroborative evidence. Applicants may be required to present proof of qualifications claimed but should not submit such proof unless it is requested. Exaggeration or misstatement or the submission of a sample of written work that is not the applicant's own will cause disqualification or dismissal from the service.

United States Civil Service Commission Basic Requirements for Mining Engineers

Applicants for the position of mining engineer must have completed successfully a full 4-year professional curriculum leading to a bachelor's degree in an accredited college or university or have had 4 years of successful and progressive experience in technical engineering comparable to that which would have been acquired through successful completion of a full 4-year engineering curriculum in an accredited college or university.

Tentative Selection and Probational Appointment

After a coal-mine inspector or engineer has been selected from the Civil Service register for possible employment, he is interviewed by a Bureau of Mines official to determine his fitness for the position. If the interview discloses that the applicant is unsuitable for employment, he is no longer considered for the position. If the applicant is considered favorably and has passed the required medical examination, he is given a 1-year probational appointment. Probationers who do not meet Bureau of Mines standards are separated from the service in accordance with Civil Service regulations.

TRAINING OF PERSONNEL

Inspectors and engineers usually are given a 4-week course of intensive training in technical matters and Bureau policy at the Bureau of Mines Central Experiment Station, Pittsburgh, Pa., before being assigned to field headquarters. However, in those instances when an inspector is employed to replace an inspector who leaves the service, the new inspector is given on-the-job training first by accompanying experienced inspectors and completes the 4-week training course at Pittsburgh as soon as enough replacements are employed to constitute a class.

The classwork includes lectures, demonstrations, and laboratory work covering such vital subjects as roof control, haulage, mine rescue training, first-aid training, causes and prevention of mine fires and explosions, mine gases and methods of detection and control, mine electricity, ventilation, explosives, methods of collecting and analyzing dust and air samples, method of conducting a coal-mine inspection, method of preparing inspection and investigation reports, operation of automobiles, and general policy matters.

New inspectors are required to accompany experienced inspectors until they have demonstrated their ability and are authorized by the Director to conduct inspections without immediate supervision. They are admonished to go slowly with their first inspections and to be very careful and thorough so that hazards are not overlooked. The need for thoroughness is emphasized throughout the training period and is re-emphasized from time to time thereafter so that there is no misunderstanding of Bureau policy.

One or more coal-mine inspectors of outstanding ability are assigned in certain field office areas to assist the field officials in supervising the coal-mine inspectors under their jurisdiction. The supervising inspectors accompany the regular inspectors, instruct them when necessary to improve the quality of their work, and submit reports of their observations for critical review and appropriate action.

Coal-mine inspectors and engineers are called upon from time to time to teach the Bureau's accident-prevention courses, to address meetings of persons interested in mine safety, and to confer with groups of mining men - all for the purpose of selling safety. To assure that the inspectors and engineers are better equipped to perform these duties effectively, they have been given a short course of instruction in the conference method of teaching by a nationally known authority on vocational industrial training. Personnel of the McAlester Station completed this training in 1954.

NATIONAL PROMOTION POLICY

A new national promotion policy for Federal coal-mine inspectors was approved and became effective January 1, 1955. It provides in part as follows:

> Policy with regard to grades of coal-mine inspection personnel is as follows:
>
> Grade GS-13 is usually associated with managing a subdistrict office covering a very large geographic area (one or more States) in which there is scattered coal mining or a small area in which coal-mining activity and the complexities of operation are concentrated to the extent that it is necessary to impose responsibilities and complexities of management on a supervisor equivalent to that intended by classification standards for grade GS-13. There are exceptions to this in that some highly specialized jobs not involving management of offices or employees are classified to grade GS-13.
>
> Grade GS-12 is associated with minor management responsibilities with corresponding reduction in supervision, management, and specialized technical assignments of difficult and complicated nature requiring exercise of above-average judgment and tact.

Grade GS-11 is considered the journeyman grade for coal-mine inspection with closer supervision and more limited exercise of independent judgment.

Grade GS-9 is considered the apprentice grade for coal-mine inspection. Covers inspections with inspectors of higher grades and inspections of the least difficult mines without immediate supervision as part of the inspector training program.

It is the established policy that additions to the coal mine inspection staff shall be made in grade GS-9, and that it is the responsibility of the District Supervisor to provide training and supervision for inspectors in grade GS-9, particularly during the probationary or trial period, necessary to develop and train those individuals and prepare them for journeyman status. The District Supervisor shall subject those individuals to appropriate tests to determine their proficiency. On full proof of an inspector's ability to assume journeyman status, the District Supervisor shall so certify with recapitulation of evidence in support of his finding. After approval by the Assistant Director—Health and Safety, the personnel office having jurisdiction shall proceed with promotion of the individual to grade GS-11 at the then place of employment if the inspector is already doing or is to be immediately assigned in that area for a considerable portion of time to the kind of inspection work classifiable to grade GS-11 subject to limitations inherent in law and regulation. Promotions made other than by certification from the register shall be reported monthly to the Chief Personnel Officer so that the register may be kept current.

It is the policy that the number of positions in each grade shall be flexible and determined by the exigencies of the work as it expands or contracts with changes in the industry, or in the goals set within the Bureau. A system for promotion from grade GS-9 to GS-11 and GS-11 to GS-12 is provided hereinafter.

Inasmuch as the work and responsibilities of Grade GS-13 positions require exercise of judgment, tact, initiative, and other special qualifications not practical for measurement by a fixed formula, such as is used for the promotion register, positions in grade GS-13 shall be filled only on the basis of selection by joint action of officials in higher echelons.

It is the policy that coal mine inspection positions shall be occupied only by men who are physically fit to perform at any time the rigorous work involved. To insure compliance with this policy it shall be the duty of each District Supervisor to see that each coal-mine inspector is given a full physical examination at Federal expense at intervals of not more than five years, preferably three years after age 60, or more frequent if considered necessary. This examination shall include full-plate chest X-ray and electrocardiogram, and shall be concluded with a statement by the examining physician as to the man's ability to perform the arduous work of a coal-mine inspector. If an inspector is not able to perform such arduous work, the District Supervisor shall move through appropriate channels, for disability retirement of the individual or other corrective measures. This

procedure shall be applied to all persons whose job title is Coal Mine Inspector in grades GS-9, GS-11, GS-12, and GS-13, and all other coal mine inspection personnel, regardless of grade or title, whose position requires that they perform such arduous work.

ORGANIZATION

The Congress appropriated $3,645,000 to carry on the work of the Division of Coal-Mine Inspection during the fiscal year 1955. This provided for a total force of 273 coal-mine inspectors, 34 mining engineers, 6 mining-electrical engineers, 5 mining-explosives engineers, 10 electrical inspectors, administrative officials, and supporting personnel.

Coal-mine inspectors, electrical inspectors, and engineers are headquartered at strategic places in the coal-producing areas in the United States.

Reorganization of the Health and Safety activities of the Bureau of Mines based on a report of a survey team made up of persons from private industry who were appointed by the Secretary of the Interior became effective December 19, 1954, in accordance with Administrative Order 695, issued by the Director of the Bureau of Mines, December 8, 1954, which is presented in part herein as Appendix A.

INSPECTION PROCEDURE

The Federal Mine Safety Codes are used as the bases for determining unsafe and unhealthy conditions and practices in all coal mines inspected, and the safety provisions of Title II, Federal Coal Mine Safety Act, are mandatory at all coal mines that employ 15 or more individuals underground regularly.

The standard procedure for inspecting all coal mines (under Title I and Title II), briefly, is as follows: Generally, notification of an inspection is not given to the mine operators or the miners. The regular inspection may require from a day to several weeks, depending on the size of the mine, the thickness and pitch of coal beds, the system of mining, the degree of concentration of working places, the prevalence of hazardous conditions and practices, and other conditions. The inspector is required (a) to inspect every working place in the mine, all active haulageways, entrances to abandoned workings, accessible old workings, airways, escapeways and other places where men work or travel or where dangerous conditions may exist, electric equipment and installations, haulage facilities, first-aid equipment, ventialtion facilities, communication installations, roof and rib conditions, blasting practices, surface plant, etc.; (b) to test for gas and oxygen deficiency in all mines and to collect samples of mine air and mine dusts for chemical analysis, if necessary, to determine precisely the conditions with respect to noxious and explosive gases, oxygen content, and coal dust and rock dust.

In multiple-shift operations the inspector is required to devote part of his time to inspection on each shift so that hazards are not inadvertently overlooked and to spend enough time at the active working faces to observe, wherever practicable, a complete cycle of operations, including cutting, drilling, blasting, loading, hauling, support of roof, etc.

To assure that the principle of States' rights would be preserved, Title II provides for joint Federal-State inspections when a State desires to cooperate in such activities. The Director of the Bureau of Mines is required by the act to cooperate with the official mine-inspection or safety agencies of the coal-producing

States. Title II provides further that any State desiring to cooperate in making joint inspections may submit a State plan for carrying out the purposes of this part of the act. Such plans shall designate an authorized State safety or inspection agency to administer the plan and give assurance that such agency will employ an adequate and competent staff of inspectors, assign its inspectors to participate in inspections in the State under Title II, and make such reports to the Director of the Bureau of Mines as the Director may require from time to time. The Director, however, is required to approve any State plan that complies with the specific provisions. The Director may withdraw his approval and declare such a plan inoperative if he finds that the State agency is not complying with the spirit and intent of any provision of the State plan.

Where a State plan is not adopted, the Federal coal-mine inspector is responsible under Title II to take 1 of 2 courses of action if he finds certain hazardous conditions during his inspections:

a. The first action involves imminent danger. If a Federal inspector finds danger that a mine explosion, mine fire, mine inundation, or man-trip or man-hoist accident will occur in a mine immediately or before the imminence of such danger can be eliminated, he issues a written order requiring the operator of the mine to cause all persons, except certain public officials and those specifically permitted by law to correct the conditions, to be withdrawn from and debarred from entering the area described in the order. The operator is not permitted to resume normal operations in such an area until: (1) The conditions specified in the order are corrected to the satisfaction of three duly authorized representatives of the Bureau of Mines appointed by the Director after receiving an application from the operator for annulment or revision of such order, and the order has been annulled or revised by the Director, or (2) the Federal Coal Mine Safety Board of Review finds that, after receiving an application from the operator for annulment or revision of the order and after a formal hearing, the condition described in the order was erroneous or no longer exists.

b. The second action involves one or more violations of the Mine Safety Provisions set forth in Sec. 209. If a Federal inspector finds that any such mine safety provision is being violated and that the violation does not cause danger that an explosion, fire, inundation, or man-trip or man-hoist accident will occur in such mine immediately or before the imminence of such danger can be eliminated, he is required to issue a written notice to the operator, giving the operator a reasonable time for correcting the violation. If, upon making his special inspection after the expiration of such reasonable time to determine whether the violation has been abated in the time originally specified, the Federal inspector finds that the violation has been totally abated, he issues another written notice to that effect. If the inspector finds that the operator should be given additional time to abate the violation, he grants an extension of time in writing. If, however, the violation is not abated and the Federal inspector finds that circumstances, such as obvious lack of effort by the operator to correct the condition, do not justify granting an extension of time, he issues a written order requiring the operator to cause all persons, except certain public officials and those specifically permitted by law to correct the conditions, to be withdrawn from and debarred from entering the area described in the order. Here again, the operator is prohibited from resuming normal operations in the affected area until the order is annulled or revised by the Director of the Bureau of Mines or by the Federal Coal Mine Safety Board of Review under the same procedure as described for imminent dangers. Any final order by the Board is subject to judicial review by the United States Circuit Court of Appeals, upon notice of appeal by the Director or the operator.

Where a State plan has been adopted, no representative of the Bureau shall inspect a mine under Title II unless a State inspector participates in such inspection in accordance with such plan, except where, in the Director's judgment, an imminent danger is deemed to exist and participation by a State inspector would unreasonably delay such inspection. If a Federal inspector issues a withdrawal order citing an imminent danger under Sec. 203(a) and a State inspector did not participate in the inspection on which such order is based, the mine operator may request the State agency to assign an inspector to inspect the mine, which must be complied with promptly.

Title II further provides that no withdrawal order shall be issued as a result of failure of an operator to abate a violation of a mine safety provision that does not present an imminent danger under Sec. 203(a) at the expiration of the time originally set or extended for abatement at a mine in a State in which a State plan is in effect unless a State inspector participated in the inspection and concurs in such order. If the State inspector does not concur in such order, the operator or the State or Bureau representative may apply to the chief judge of the United States District Court for the district in which the mine is located for appointment of a qualified independent inspector to inspect the mine. If, after such inspection, either the independent or the State inspector concurs in the order, it shall be issued.

Withdrawal orders issued with respect to a mine in a State in which a State plan is effective are not subject to review by the Director but are subject to review by the Federal Coal Mine Safety Board of Review.

In response to requests, sample plans for State participation were drafted and submitted to Alabama, Arkansas, Kansas, Montana, North Carolina, Oklahoma, Washington, and Wyoming to serve as guides in formulating plans for submission to the Director for his approval. On September 29, 1952, a plan submitted by Wyoming was the first to be approved by the Director. Since then five additional plans have been approved. The States involved and the effective dates of the plans are: Washington, December 17, 1952; Oklahoma, February 13, 1953; North Dakota, February 16, 1953; North Carolina, March 27, 1953; and Alaska, June 15, 1953. During 1954, 17 joint State-Federal inspections were made in Wyoming, 21 in Washington, 18 in Oklahoma, and 4 in Alaska, a total of 60. (See Appendix B, table 1.)

Each coal-mine inspector is assigned a district comprising mines that he inspects regularly. This procedure was adopted in 1948 and has resulted in a greater personal interest on the part of the inspector to have the mines under his jurisdiction in the safest condition possible and to keep accidents in them to a minimum. Inspectors are responsible for devising ways and means of reducing accidents in their respective districts, and they are required to improve the effectiveness of their inspections by:

a. Determining the outstanding causes of accidents at the mine to be inspected; this information is used during the inspection as a guide in detecting hazards.

b. Discussing observed hazards and means of correction with the accompanying official at the time the hazard is discovered, with the mine safety committeemen, when feasible, and with high company officials when a conference can be arranged.

c. Enlisting the cooperation of labor, management, State inspection personnel, and all other safety-promotion agencies.

d. Becoming acquainted with management, the officials of the mine workers' organization, and the mine safety committeemen.

e. Attending local union meetings occasionally to discuss safety with the members and endeavoring to promote cooperation in accident-prevention work.

f. Participating in mining institutes, Holmes Safety Association chapters and councils, and other agencies dedicated to promoting mine safety.

g. Assuming a personal interest and a definite personal responsibility in preventing accidents.

h. Investigating all fatal coal-mine accidents in the respective districts.

i. Assisting in rescue, recovery, and investigation following mine disasters.

j. Assisting mine officials to improve the methods of operation with a view toward greater efficiency, economy, and safety.

k. Conducting first-aid and mine rescue training and officiating at first-aid and mine rescue contests.

PROCEDURE FOR PREPARING AND DISTRIBUTING COAL-MINE INSPECTION AND INVESTIGATION REPORTS

A preliminary report is prepared by the inspector according to standard regulations following the completion of a regular inspection of a coal mine that employs less than 15 men underground only if hazards of primary importance are observed. Preliminary reports are not prepared for strip mines. Mines that employ less than 15 men underground and strip mines are hereafter called Title I mines.

The preliminary report, indicating unsafe conditions and practices considered of primary importance, is prepared by the inspector and posted by him at the mine within 1 day following completion of the inspection. Typed copies of the preliminary reports are distributed by the field offices of the Bureau of Mines to the mine officials, the State mine-inspection agency, the district and national offices of the mine workers' organization having jurisdiction at the mine, the Washington Office of the Bureau of Mines, and the Geological Survey if the mine is on the public domain or Indian land.

Preliminary reports are not prepared following inspections of mines that employ regularly 15 or more men underground, hereafter called Title II mines. In lieu thereof, withdrawal orders, citing imminent dangers under Sec. 203(a), or notices, citing violations of Sec. 209, Mine Safety Provisions, that do not appear to be imminent, as provided under Sec. 203(c), or an order classifying the mine gassy under Sec. 203(d) are issued by the inspector to the mine operator during or at the completion of an inspection, and copies are posted on the mine bulletin board. Typed copies of such notices or orders are distributed by the field offices of the Bureau of Mines to the mine officials and the same agencies that would receive copies of the preliminary reports.

A final report on each inspection, prepared promptly by the inspector, contains a general description of the property and of conditions and practices observed during the inspection. All unsafe conditions and practices are recorded in detail, and proper recommendations are made to correct them. Where applicable,

violations of the safety provisions of Title II that are observed during the inspection are cited, and the action taken to have the violations abated is indicated. Results of chemical analyses of dust and air samples collected during the inspection are listed in the report to provide additional information with respect to conditions at the mine. Substandard and dangerous conditions that are eliminated during the inspection and between inspections are also presented.

Final reports on inspections of coal mines are prepared and mimeographed in the field offices and distributed from there to management, the State mine-inspection agency, the national and district offices of the mine workers' organization, the Joint Industry Safety Committee (bituminous-coal mines that are affiliated with the UMWA), the Washington Office of the Bureau of Mines, and the Geological Survey if the mine is on the public domain or Indian land.

Enough reports are reviewed in the Washington office after they have been transmitted to all concerned to assure that the rules for preparing and distributing reports are being followed and to obtain information on serious hazards and violations of the safety provisions of Title II.

A press release covering salient features of certain reports is prepared and sent to the newspapers in the area where the mine is situated.

The posting and distribution of the reports, the press releases covering them, and the filing of the reports in the Bureau of Mines field and departmental offices for public inspection constitute compliance with that part of the act requiring publication and dissemination of findings.

Reports covering investigations of all fatal coal-mine accidents, of nonfatal serious roof-fall accidents, of major and minor coal-mine disasters, and of mine fires and ignitions that are not of disaster proportions are prepared, and they are distributed by the field offices to all agencies and persons that ordinarily would receive copies of the regular inspection reports.

FOLLOWUP PROCEDURE

Under the mandatory provisions of Title II, special inspections are made by an inspector at the expiration of time periods set or extended as reasonable for abatement of violations of Sec. 209 and, in instances where men have been withdrawn, upon orders from the Director of the Bureau, in response to a request from the operator, to determine whether the violations have been totally or partly abated.

The inspector can order an operator to withdraw men from a mine or a portion of a mine summarily if an imminent danger is deemed to exist or if the operator has not made a reasonable effort to abate a violation of Sec. 209 at the expiration of the time that has been set or extended for abatement.

Sec. 205 provides for creation of a Federal Coal Mine Safety Board of Review to hear and determine applications filed pursuant to Sec. 207 for annulment or revision of orders made pursuant to Sec. 203 or Sec. 206. In compliance with these provisions, on August 21, 1952, the President appointed A. U. Miller, C. R. Ferguson, and J. G. Solari to serve as members of the first Board. Mr. Miller was named chairman. During 1953, E. R. Price, manager of coal properties, Inland Steel Co. (retired), was appointed as the operators' representative in place of Solari, resigned, and Edward Steidle, Dean Emeritus, School of Mineral Industries, Pennsylvania State University, replaced Miller as chairman. Mr. Ferguson continues to serve as the representative of the coal-mine workers.

Sec. 206 provides that an operator may apply to the Director for annulment or revision of an order issued under Sec. 203. However, where a State-participation plan is in effect, application for annulment or revision of a withdrawal order must be made directly to the Federal Coal Mine Safety Board of Review.

Inasmuch as the Federal coal-mine inspectors have no authority to require compliance with their recommendations made under the provisions of Title I, every reasonable and practical effort is made to get these unsafe conditions and practices corrected. One method is to enlist the cooperation of the State mine-inspection agencies, which generally have authority to require the correction of hazards. When an inspector observes unduly hazardous conditions or practices that are not covered by Title II while inspecting a mine, he informs the local mine officials. If prompt action is not taken to correct the hazards, he so advises the mine safety committeemen and also the Bureau of Mines official in charge, who promptly relays the information to the State mine inspector and the head of the State mine-inspection agency by telephone, confirmed by letter, or by letter only, as the exigencies of the case indicate. In addition, the statement of the hazard and the recommendation for its correction are capitalized in the final report to call special attention to them. Such procedure has resulted in the elimination of many very serious hazards in the mines.

The condition of many coal mines in the Nation is evident when it is known that 39 percent of all inspections of mines exempted from the provisions of Title II made during 1953 revealed hazards that were serious enough to justify sending special notices to the heads of the State mining agencies. Records regarding serious hazards observed in coal mines that are not covered by the mandatory provisions of Title II are included in Appendix C of this report.

Such followup procedures undoubtedly have considerably improved practices and conditions in many mines and reduced coal-mine injury rates.

Three of the 325 orders requiring withdrawal of men from underground areas have been appealed to the Federal Coal Mine Safety Board of Review; and one of these, issued under a State-participation plan, could not be appealed to the Director under the provisions of the act. In each instance where a withdrawal order has been issued and the operator has appealed to the Director of the Bureau of Mines, claiming that the dangerous condition was corrected, such appeals have been acted upon promptly. The Bureau is as much interested as the operators in causing no undue delay in reopening mines after violations of the law are corrected. In each instance, after prompt special investigation by three duly authorized representatives of the Bureau of Mines, the Director verified that the conditions had been corrected, the inspector's order was annulled, and the mine was permitted to resume normal operation.

During the 30-month period, ended December 31, 1954, in which the Federal Coal-Mine Safety Act has been in effect, 7 applications for annulment of gassy classification orders under Sec. 203(d) were made to the Director; 5 of these applications were denied, and 2 of the orders were annulled. Three of the Director's decisions denying annulment were appealed to the Federal Coal-Mine Safety Board of Review; 1 of these was upheld by the Board, and 2 were reversed. One application for annulment of a gassy classification order that was made directly to the Board was denied. One withdrawal order issued under a State-participation plan according to the provisions of Sec. 203(a) citing amminent explosion dangers was annulled by the Board after finding that the dangers had been eliminated, and the Board revised one withdrawal order issued under 203(c) for failure to abate violations of Sec. 209(d)(9) by extending the time for abatement to permit training enough men in the

maintenance, use, and limitations of permissible flame safety lamps to make the required tests for gas. Upon request of the operator the Bureau provided personnel for this specialized training, at the completion of which the violation was abated and the order was annulled by the Director. See Appendix D.

REGULAR INSPECTION WORK ACCOMPLISHED

According to a Bureau of Mines survey, 8,360 coal mines were operated more or less regularly during 1954. A tabulation showing the number of coal mines (by types and States) operated in 1954 is included in table 1 of Appendix E.

Reference to the performance data in Appendix E will reveal that:

a. 10,519 regular inspections of coal mines were made during 1954 (table 2).

b. 72,566 regular inspections of coal mines have been made since 1941 when Public Law 49 became effective (table 2).

c. 4,293 of the 5,515 active coal mines employing less than 15 men underground (Title I mines) were inspected during 1954, and the average number of inspections per active small underground mine was 1.1 (table 1 and table 3).

d. 1,498 of the 1,570 active coal mines employing 15 men or more underground (Title II mines) were inspected during 1954, and the average number of inspections per active larger underground mine was 2.5 (table 1 and table 3).

e. 517 of the 1,275 active strip mines were inspected during 1954, and the average number of inspections per active strip mine was 0.4 (table 1 and table 3).

f. The average time required to make a regular inspection and to prepare the inspection report, including travel time, was 1.6 days for strip mines, 1.8 days for Title I underground mines, and 4.6 days for Title II mines, excluding special inspections (table 4). The average total time to complete an inspection of a Title II mine, including special inspections, is 5.4 days (table 5).

g. 2,727 special inspections required under Title II were made to determine whether violations cited under Sec. 203 had been abated. This represents an average of 0.7 special inspection and 0.8 additional man-day inspecting for each regular inspection of a Title II mine (table 5).

During 1954 Federal inspectors reported 91,517 violations of the Federal Mine Safety Codes while inspecting 4,810 Title I mines, an average of 19 violations per Title I mine inspected (see Appendix F). Thirty-nine percent of the inspection reports on these mines transmitted indicated dangers of a serious nature that were not corrected (see Appendix C), and only 16 percent of all the violations reported were corrected (see Appendix G).

Federal inspectors reported 30,113 violations of the Federal Mine Safety Codes while inspecting 1,498 Title II mines, an average of 20 violations per Title II mine inspected (see Appendix F). Eleven percent of the inspection reports on these mines transmitted indicated dangers of a serious nature that were not corrected (see Appendix C), and 52 percent of the violations of the codes were corrected (see Appendix G).

In all, 8,012 violations of the mandatory mine safety provisions of Title II of the Federal Coal Mine Safety Act were observed while making 3,894 inspections

of these mines during 1954, an average of 2.1 per inspection. However, 5,079 (63 percent) of these violations were corrected before the inspections were completed, and 2,933 original notices (Form B) were issued at 943 mines granting reasonable time to abate violations that required more time to correct. Subsequent special inspections revealed that 2,955 violations had been totally abated, and 652 notices (Form C) were issued granting additional time for abatement of others. About 95 percent of the violations for which notices were posted were being abated at the expiration of the time originally set or the time as extended. Fifty-eight withdrawal orders citing imminent dangers under Sec. 203(a) (Form A) were issued at 43 mines during 1954, making a total of 98 such orders at 72 mines since July 16, 1952 (see Appendix B, table 1 and table 2, for imminent dangers cited by States). Seventy-six withdrawal orders under sec. 203(c) (Form D) were issued at 38 mines during 1954 for failure to abate violations within a reasonable time, making a total of 227 such orders at 110 mines since July 16, 1952 (see Appendix B, table 1 and table 3, for violations cited). Eighteen orders (Form B-1) were issued classifying mines gassy under Sec. 203(d) during 1954, making a total of 84 of such orders issued since July 16, 1952 (see Appendix B).

No violations of the Federal Mine Safety Codes were observed while inspecting 24 Title I mines and 65 Title II mines (see Appendix F), and violations of Sec. 209 of the Federal Coal-Mine Safety Act were not observed while inspecting 554 Title II mines (see Appendix B); 53 of these mines were free of violations of the codes and the act. These mines are identified in tables 1, 2, and 3, Appendix H.

The Federal Coal Mine Safety Act requires that the Director shall cause an inspection of each mine coming under the provisions of Title II to be made by a duly authorized representative of the Bureau at least annually. However, it is believed essential that these Title II mines should be federally inspected at least three times a year, small underground mines not covered by Title II should be inspected at least twice a year, strip mines should be inspected once a year, and spot-check inspections should be made (between regular inspections) at those mines where experience indicates lack of compliance with the provisions of the act. These minimum requirements are desirable because the provisions of Title I of the act are purely recommendatory, and Title II contains no penalties for noncompliance with its mandatory characteristics between inspections.

In addition to meeting the foregoing mine-inspection schedule, Federal inspectors are required to perform special duties, such as investigating fatal accidents and nonfatal, serious roof-fall accidents, making dust surveys, reviewing reports, working in supervisory capacities, assisting with rescue, recovery, and investigative work after mine disasters, teaching the Bureau's accident-prevention classes, and various other jobs. These special assignments are quite essential to comply with the provisions in the Federal Coal Mine Safety Act and to obtain the greatest benefits from the regular inspections.

A tabulation of the force of inspectors employed on December 31, 1954, is given in Appendix I.

SPECIAL WORK ACCOMPLISHED

Although the routine inspections of coal mines and distribution of inspection reports are primary functions of personnel of the Division, it is realized that the effectiveness of the inspections is enhanced when mine supervisory personnel and mine workmen have enough technologic and practical knowledge of modern concepts of coal-mine safety to recognize an unsafe condition or practice when it exists or is

developing and know how to correct it. The opportunity to obtain such knowledge through the Bureau of Mines was not available generally before 1947, principally because funds were not made available for conducting the necessary training.

The need for providing this opportunity is recognized in section 106 of the Federal Coal Mine Safety Act, which authorizes and directs the Secretary of the Interior, acting through the Bureau of Mines, to expend the funds made available to him to advance health and safety in coal mines and prevent or relieve accidents and occupational diseases in mines in such lawful manner as he may deem most effective in the light of the information obtained under the act to accomplish the object for which such funds are granted.

To comply with such directive, the outstanding special work accomplished during 1954 is described hereafter. A tabulation of miscellaneous special work is included in Appendix J of this report.

Coal-Mine Accident Prevention Course for Miners

The National Bituminous-Coal Wage Agreement provides that:

> At each mine there shall be a Mine Safety Committee selected by the local union. The Mine Safety Committee may inspect any mine development or equipment used in producing coal. If the Committee believes conditions found endanger the life and bodies of the mine workers, it shall report its findings and recommendations to management. In those special instances where the Committee believes an immediate danger exists and the Committee recommends that management remove all mine workers from the unsafe area, the operator is required to follow the recommendation of the Committee.

The Anthracite Wage Agreement provides that:

> Mine Committees, acting on the request of individual employees or upon their own personal knowledge, shall have the right to report to management unsafe conditions affecting operations or equipment. In such cases, the Mine Committees shall have the right, accompanied by representatives of management, to make necessary inspections of property or equipment for the ascertainment of actual facts. In the event such conditions, when reported, are not satisfactorily corrected, the Mine Committee shall request action by the State and Federal inspectors.

To assure that members of these committees would be well versed in the provisions of the Federal Mine Safety Codes and thereby be better equipped to recognize unsafe conditions and practices that exist or are developing and to learn the proper means of overcoming them, the Bureau of Mines, in cooperation with the United Mine Workers of America, inaugurated a Coal-Mine Accident-Prevention Course for Mine Safety Committeemen in January 1947. The course covers the practical and some technical aspects of modern principles of coal-mine safety and requires 20 hours of classroom work. It had such an enthusiastic endorsement by mine safety committeemen and mine operators that it was decided to extend the enrollment opportunity to all mine workmen. The popularity of the training is attested by the record. From the time the revised training program was begun on Januray 1, 1947, to December 31, 1954, 107,690 mine safety committeemen and miners had completed the course. Included in these figures are 3,183 men who completed special on-the-job accident-prevention training, which was initiated at a large, eastern coal mine in

February 1952. Usually the classes are conducted by Federal coal-mine inspectors who have been especially trained and authorized to carry on instructional work.

In addition, 1,697 have received specialized training in the maintenance, use, and limitations of permissible flame safety lamps to qualify them to make proper tests for gas in places where electric machines are operated in face areas in accordance with the provisions of Sec. 209 (d)(9) of the act.

Coal-Mine Accident-Prevention Course for Supervisors

Congress appropriated funds to continue the employment of mining engineers to train coal-mine supervisors in the modern principles of mine safety. The Bureau's Coal-Mine Accident-Prevention Course for Supervisors requires 40 hours of classroom instruction and covers all technoligic as well as practical phases of safety as applied to: Surface facilities; timbering and roof control; the transportation, storage, and use of explosives; ventilation and mine gases; coal dust and rock dust; haulage; electricity; safeguarding equipment; fire prevention and control; and other miscellaneous items. The course includes lectures, class discussions, actual demonstrations, and the use of visual aids, such as motion pictures, slides, and blackboard sketches.

This training program has been successful, and from March 1948 when the revised course was first offered to December 31, 1954, 19,310 coal-mine supervisors and others aspiring to such positions completed the training.

Electrical Safety Course

An outline for a course in electrical safety entitled "Electrical Fundamentals and Principals for Coal-Mine Electricians and Supervisors" was prepared by personnel of the Division, and initial training in the industry was begun in 1954. To date 49 coal-mine personnel, 9 State inspectors, and 15 Federal inspectors have completed the course in Alabama. Other classes are in progress in other States, and this worthwhile program is being expanded rapidly.

The Holmes Safety Association

Coal-mine-inspection personnel take an active interest in the Holmes Safety Association, which has been sponsored by the Bureau of Mines since 1926, when it was adopted as part of the Bureau's safety educational program to promote health and safety in the mineral industries through the cooperative efforts of management and labor and State and Federal agencies. In 1954 the Bureau began to intensify its efforts to expand operations of this organization to mining areas in all parts of the United States and is having success. This stepped-up program is being conducted by specially trained Division of Coal-Mine Inspection personnel in the coal-mining areas.

Experience has proved that injury rates are lower than average in mines that have membership in this association.

Investigation of Fatal Coal-Mine Accidents

The Bureau of Mines has investigated major mine disasters since its inception in 1910 as part of its accident-prevention program, and the conclusions drawn from these investigations have been used as a basis for recommending measures to prevent recurrences. The Bureau also has investigated explosions and fires in which less

than five or no lives were lost, but before 1950 it was not general practice to investigate fatalities resulting from occurrences other than mine fires or explosions. The Bureau has long recognized the need for a comprehensive study of fatal accidents, but the task was too great for the limited available personnel. On the basis of the improved rate at which fatalities were occurring in coal mines and the increases in inspection personnel provided by Congress in recent years, investigations of all fatal accidents have been made since February 10, 1950. In addition, investigations of all reported serious nonfatal roof-fall accidents are now being made as part of the nationwide campaign to prevent roof-fall injuries. A report of each investigation is prepared by the Federal inspector, and it is distributed to the same agencies and persons that ordinarily would receive copies of the regular coal-mine-inspection report. The report gives the facts about the accident, presents the inspector's conclusions regarding the cause, and includes appropriate recommendations for preventing similar occurrences.

The information in the reports covering the investigations of coal-mine fatalities that occurred during the calendar years since 1950 has been condensed and published annually. It is particularly useful to officials of coal companies and of the mine workers' organizations in planning accident-prevention programs; to safety directors, inspectors, instructors, and supervisors who need such information to carry out their duties more effectively; and to mine workers who must know the causes of accidents to be better able to prevent injury to themselves and their fellow workmen. The ultimate objective is to provide information that will be helpful in preventing accidents.

This is the first time in the history of coal mining that the Bureau of Mines or any other agency or person has assembled, on a nationwide basis, detailed reports on the investigations of all fatalities occurring in coal mines of the United States and Alaska.

Roof-Control Work

Accident statistics have indicated for years that falls of roof and coal cause more than half of the fatalities that occur in coal mines, and this record has challenged all the forces interested in improving the accident rates in the coal-mining industry. The Bureau of Mines has done a considerable amount of research on mine-roof control when funds were available, but as late as 1948 no person or agency produced any new or improved means of satisfactorily solving the problems presented by this No. 1 killer of mine personnel. The Bureau has realized that, to reduce coal-mine injuries to a greater extent it would be necessary to find better methods of roof control, and in 1948 the Bureau's efforts in that direction culminated in the general introduction in the coal-mining industry of a new means of roof control known as roof bolting. The basic principle involved is to prevent the initial sag in exposed roof strata by converting them into a rigid beam, with steel bolts set in holes drilled in the roof rock. The bolts must be installed as soon as the roof is exposed by the normal process of mining.

After enough experimental work was conducted to prove the practicability and safety of bolting under controlled conditions, the method was given wide publicity in Bureau of Mines publications and in the trade journals. To satisfy the demand of mine operators for the Bureau's suggestions for installing roof bolts and to assure that the method would not be condemned as a failure because of improper installations, the Bureau trained certain Federal coal-mine inspectors and engineers to qualify as expert consultants in roof bolting; these experts are now headquartered in coal-mining areas where their services are needed. Generally, the mine

operators obtain the advice and recommendations of the Bureau experts before any bolts are purchased, and some States now require mine operators to obtain a permit from the State inspection agency before roof can be bolted. Such wise precautions have contributed much to the success of this new method of roof control.

Before roof bolting is adopted in any mine, the Bureau of Mines recommends the following procedure:

Controlled experiments to determine whether roof bolting is applicable should be made in conformance with the procedures that have been worked out by the Bureau of Mines. Bureau experiments are made under controlled conditions with auxiliary conventional supports during the initial experimentation. After a safe and economical method of bolting is determined, no deviation from this method should be made without undergoing a new experimental period. Also, if roof conditions change radically from those encountered during the initial experimental period, a new experimental period should be undergone.

Federal coal-mine inspectors observe roof-bolting procedures during their regular inspections of coal mines and report deviations from the established plans along with other substandard practices of roof support.

The attitude of mine operators toward roof bolting is described best by saying that, since 1948, when the method was generally introduced to the industry, roof bolts have been installed in 580 coal mines. They are used exclusively in a number of large mines; according to the records, when installed as recommended by the Bureau of Mines, roof bolts simply and effectively prevent falls of roof. The installations have not been made in enough mines to have a notable effect on the accident rates in the entire coal-mining industry. However, the use of roof bolts is expanding rapidly, and the success attained at mines where they are being used indicates what may be expected as their use becomes more general.

The introduction of roof bolting to the coal-mining industry marks another major contribution of the Bureau of Mines in its efforts to fulfill the primary objective of the Congress in establishing the Bureau in 1910 - to prevent accidents in the mineral industries.

Supplemental to the foregoing roof-control activities, a mining engineer has made a thorough study of the possibilities of using various protective coatings to prevent disintegration of roof rock, with special attention to health and fire hazards involved. This work has been completed, and a set of safety standards covering roof coating has been prepared for the use of Federal inspectors and the industry.

As a further means of reducing the incidence of roof-fall accidents, the Bureau of Mines initiated a Coal-Mine Roof-Control Course in May 1951. It consists of about 30 minutes to 1 hour of lecture and discussion and is presented to coal-mine officials and employees by Federal coal-mine inspectors, usually after inspection of a mine has been completed. The course is designed to impress upon mine personnel the need for more adequate roof-control measures and to make all concerned more roof conscious; it was introduced in the industry in July 1951, and from that time to December 31, 1954, 218,277 mine personnel completed the training.

Although systematic timbering, use of roof bolts, and training miners to be constantly alert to roof conditions have been effective in reducing fatalities, roof falls still cause over half of all coal-mine fatalities, most of these in the areas

within 12 feet of the working faces where the stability of the newly exposed roof cannot be immediately determined. In an effort to provide a means to guard against these unforeseen dangers, the Bureau is arranging an intensified program of research and investigation to develop mobile or portable devices that can be readily advanced with the working faces to protect workmen in the critical face areas. Success in this endeavor would be an outstanding advance in safety for the industry.

Late in 1954 an intensive 1955 national campaign to prevent roof-fall accidents was organized. This movement was initiated by coal-mine labor and supported by management. To reach the objective, the cooperation of all agencies that can contribute to the success of such an endeavor has been enlisted. Such agencies include: The mine workmen; supervisory and management officials; State departments of mines; national and local coal associations; local, district, and international headquarters of the United Mine Workers of America; editors of publications serving the coal-mining industry; newspapers circulated in coal-mining areas; national, district, and local institutes or safety organizations serving the coal-mining industry; carriers of compensation insurance; district and local safety committees; and the Federal Bureau of Mines. The response has been spontaneous, and the Director has pledged the wholehearted support of the Bureau of Mines to do the spadework and keynote the campaign. Federal coal-mine inspectors are actively promoting this campaign through their contacts with the industry - in the mines and at safety meetings and other gatherings.

Coal-Mine-Haulage Safety Section

The Coal-Mine-Haulage Safety Section of the Division of Coal-Mine Inspection was established in December 1950 to: Reduce haulage accidents in coal mines by studying causes; further study the trend of modernization and its possible effect on safety records; establish job-safety training instruction for haulage employees based upon haulage safety fundamentals and accident experiences; conduct haulage-hazard surveys by trained personnel; and promote a safety campaign to reach all persons connected with coal-mine transportation.

In April 1951 a Coal-Mine-Haulage Safety Course was completed and introduced in the coal-mining industry. The course consists of lectures and illustrations with respect to haulage safety and is presented to mine personnel by the Federal coal-mine inspectors, usually upon the completion of an inspection. From April 1, 1951, to December 31, 1954, 122,170 coal-mine haulage employees, officials, safety committeemen, and others completed this course. In view of the comparatively few men employed in haulage operations at coal mines the number of trainees has been outstanding.

Additional activities of the section during the report period included:

1. The preparation of technical papers on coal-mine-haulage safety for publication and presentation at mining institutes.

2. Active participation in National Safety Council, American Standards Association, and American Mining Congress committees for improvement in transportation safety and efficiency.

3. Completion of a safety motion picture, The Shuttle-Car Operator.

4. Making available pertinent data relative to haulage accidents and safe practices to companies and organizations requesting such service.

5. Completion of several haulage surveys at operating mines in the field.

Injury and Employment Data

One of the special duties of coal-mine inspectors and engineers of the Division is to enlist the cooperation of coal-mine operators in submitting to the Bureau of Mines reports on injury and employment statistics in compliance with Sec. 105 of the Federal Coal Mine Safety Act. If an operator needs instruction on how to fill out the proper forms, the inspector or engineer is prepared to give the advice needed. This work is done at the time the mine is being inspected and has resulted in the submission of more and better reports by mine operators.

Ventilation Surveys

Certain mining engineers of the Division of Coal-Mine Inspection are assigned to coal-mine ventilation studies, surveys, and research. Especially difficult ventilation problems are encountered in mines from time to time, and mine operators request the Bureau's assistance in solving them. Many of these studies require pressure surveys and technical calculations that the regular coal-mine inspectors usually are not equipped to make.

Explosives Surveys

Mining-explosives engineers of the Division conducted special investigations with respect to the storage, transportation, and use of explosives and blasting devices. Generally, such studies are made at the request of mine operators interested in improving the safety and economy of their operations.

The Bureau of Mines has advocated the exclusive use of permissible explosives or permissible blasting devices in coal mines for many years and has advised against the use of black blasting powder and dynamite, which have caused so many gas and dust explosions, with attendant heavy casualties. The mining-explosives engineers did a considerable amount of educational work, demonstrating to mine operators by performance tests in the mines that the use of permissible explosives is much safer than and as economical as black blasting powder. Through their efforts and the efforts of the regular coal-mine inspectors, dangerous black blasting powder has been rapidly disappearing from coal mines. The mandatory provisions of Title II ban storage, use, and handling of black blasting powder in mines coming under Title II coverage after January 16, 1953, and the mining-explosives engineers have, when requested, been of great assistance to coal-mine operators in making the required changeover to safer methods of breaking down the coal efficiently.

Electrical Surveys

The mining-electrical engineers and electrical inspectors of the Division conduct special technical investigations of electrical facilities and installations in coal mines, generally at the request of mine operators. The engineers also are assigned to cooperate with the industry in conducting research work on electrical apparatus with a view toward designing safer equipment. The electrical inspectors also advise and assist the coal-mine inspectors in making determinations of the status of permissible electrical face equipment as required by Sec. 209(f)(1) of t the Federal Coal-Mine Safety Act.

Considerable research was done in 1954 to develop an equivalent protective device to replace the frame-grounding conductor in trailing cables of mobile

electrical equipment. The reduction of insulating materials in and increased rigidity of trailing cables necessitated by incorporating an additional conductor has caused many trailing-cable failures, some with disastrous results. Manufacturers of such equipment have been cooperating, and some experimental devices have been put in service in nongassy mines to determine their safety and efficiency.

Dust Surveys

From January 21-31, 1946, a course of instruction in the Determination and Control of Unhygienic Dusts was given by personnel of the Bureau's Health Branch to certain employees of the Divisions of Safety and Coal-Mine Inspection. The object of the training was to provide each main field station with a qualified man to determine the concentration of airborne dusts in coal mines and to cooperate with dust experts of the Division of Health in conducting such surveys.

The importance of dust control in coal mines is recognized by the mining industry, and the Bureau of Mines is continuing its research work on airborne mine dusts with the view toward collecting enough data to be used as a basis for determining the concentrations of certain dusts that are considered harmful from a health standpoint and to determine the method and type of facilities best suited for controlling dusts.

On October 2, 1953, a program was inaugurated to have personnel engaged in coal-mine inspection work collect information on airborne dust conditions and dust-control practices in each coal mine inspected and submit a detailed report thereon to the Chief of the Branch of Health Research to assist in assembling data to determine the extent that occupational disease hazards exist in the Nation's mines as a result of exposure of workmen to dust-laden atmospheres. This program has been completed, and a report thereon is being prepared by the Branch of Health Research.

In promoting the adoption of roof bolting the Bureau has been aware of the health hazard introduced by drilling holes in silica-bearing strata. In keeping with Bureau policy to see that proper equipment is available to the industry, Bureau of Mines Schedule 25, Procedure for Testing Dust Collectors for Permissibility for Use in Connection with Rock Drilling in Coal Mines, was approved January 23, 1952, and amended July 23, 1952. Many dust collectors have met these requirements and have been approved and are available for use in coal mines under Schedule 25.

In an effort to provide more efficient and economical means of preventing the propagation of dust explosions in bituminous-coal mines, an engineer of the Division has been assigned to determine the possibilities of devising through intensive research new and more practical, effective, and positive means of preventing the propagation of dust explosions underground than rock dusting; to conduct research in the development of more economical and efficient means of applying rock dust on mine surfaces; and to conduct research to find improved methods and equipment for dust sampling a coal mine to determine promptly whether or not rock-dust applications are adequate. Beneficial results of this program are to be made available to the coal-mining industry.

Dust Explosions in Coal-Preparation Plants

Following several violent dust explosions in coal-preparation plants using thermal driers, the Bureau began a widespread investigation in 1954 to determine

the causes of and present recommendations to prevent fires and explosions caused by "puffs" and "flashbacks" in such plants. This investigation is continuing.

Conveyor-Belt Fires

Following a meeting in Washington in 1954 of representatives of the State Inspection Departments, coal operators, mine workmen, manufacturers, the Bureau of Mines and other interested agencies, a committee was appointed to investigate the causes of belt fires in underground conveying systems and to recommend means of preventing such fires, including flame-resistant belts. Extensive research along this line is being carried on by Bureau personnel at the Pittsburgh Experiment Station.

Study of Natural-Gas Re-Storage Areas in Coal Fields

Because the restorage of natural gas, some at pressures above the initial rock pressures, in the exhausted sands under active coal-mining areas and the installation of high-pressure gas-transmission lines overlying active coal-mining areas present potential gas-explosion hazards in the adjacent coal-bearing strata, considerable work has been done to chart and correlate the gas re-storage fields and the gas-transmission lines within the active coal-mining areas. Division personnel cooperated with coal-mine operators and appeared before legislative committees to assist in formulating legislation to protect coal-mine workmen and mining properties.

Participation in Safety Organizations

Members of the Division of Coal-Mine Inspection take an active part in the National Safety Council, its various affiliated regional organizations, the Mine Inspectors' Institute of America, the National Mine Rescue Association, the American Mining Congress, and other national, regional, and local safety organizations throughout the United States by serving as officers and on committees and participating in the various programs.

The chief of the Division serves as secretary of the Coal-Mining Section, National Safety Council, and is editor of the Section's Monthly News Letter.

Cooperation With Other Federal Agencies

In response to requests from other Federal agencies, members of the Division of Coal-Mine Inspection have accepted special assignments to: Colombia; Austria; Korea; Venezuela; and India. All of these missions have been completed.

Such assignments of engineers and inspectors serve a twofold purpose: (1) The agency to which the Bureau experts are loaned receives the benefit of their wide experience in mining, and the experts add to their fund of knowledge; and (2) the information obtained through such special work is made available to the mining industry if such action is deemed in the public interest.

Members of the Division of Coal-Mine Inspection cooperate with the Wage and Hour and Public Contract Divisions, United States Department of Labor, in administering the Public Contracts section of the Walsh-Healy Act. Under the cooperative arrangement, the Bureau of Mines field office promptly notifies the local regional office of the Wage and Hour and Public Contracts Divisions if disaster or serious hazards are found by Federal coal-mine inspectors at Title I mines under contract

to furnish coal to the Federal Government. When disaster or serious dangers are reported, employees of the U. S. Department of Labor require the mine operator to eliminate the dangers or face cancellation of the contract.

Revision of State Coal-Mining Laws

Since 1947 the Division of Coal-Mine Inspection has assisted in preparing proposed revisions of the coal-mining laws of 12 States.

The safety-regulations sections of the proposed revisions were designed along the lines of the Federal Mine Safety Codes, thus assuring more modern and standardized State coal-mining laws, and they have been adopted substantially as written in Alabama, Colorado, Maryland, Montana, Tennessee, and Wyoming. Proposed revisions of such laws for Arkansas, Illinois, Indiana, Kentucky, Ohio, and Oklahoma were prepared but either were not enacted or not introduced in the legislature.

The Bureau of Mines will continue to furnish this service to any agencies directly concerned with improving State mining laws, such as labor organizations, coal operators' associations, and State officials.

This contribution toward the reduction of injuries in coal mines is another major and vitally important step taken by the Bureau to fulfill its obligations to the coal-mining industry.

First-Aid and Mine Rescue Training

Personnel of the Branch conducted first-aid and mine rescue training for coal-mine personnel. During 1954, 13,961 persons completed the course in first aid, and 589 persons completed the mine rescue training.

Miscellaneous Special Assignments

A breakdown of the miscellaneous special assignments completed during 1954 is given in Appendix J.

ACHIEVEMENTS

This report covers the 2d full calendar year of inspection of coal mines under the Federal Coal Mine Safety Act and the 13th full calendar year of Federal coal-mine inspection work. The effectiveness of the work done by all concerned in fulfilling the principal purpose of Federal inspections - the reduction of accidents in coal mines - is revealed in part by comparing the injury records attained during equal 10-year periods before and after 1941, when the law became effective. The injury records for the calendar years 1952-54 are also given to build up a new 10-year period.

During the 10 years before Federal inspection of coal mines the fatality frequency rate per million man-hours of exposure in anthracite mines of Pennsylvanie was 1.61, and the nonfatal frequency rate 105.94. During the next 10 years under Federal inspections, the fatality rate was 1.11, and the nonfatal rate was 80.19. During the subsequent 3-year period, 1952-54, the fatality-frequency rate dropped to 1.03. Nonfatal figures for this period were incomplete at this writing.

During the 10 years before Federal inspection of coal mines the fatality frequency rate in bituminous-coal mines was 1.48 and the nonfatal frequency rate

65.81. During the next 10 years, under Federal inspections, the fatality rate was 1.18 and the nonfatal rate 55.58. During the subsequent 3 years, 1952-54, the fatality frequency rate dropped to 0.90. (See table 1, Appendix K, for details.)

A record of the number of fatal and nonfatal injuries, by calendar years, that have occurred in the coal mines of the United States since 1932 is shown in table 2 of Appendix K. Preliminary figures indicate that the number of fatalities dropped from 460 in 1953 to 395 in 1954, but the frequency rate increased from 0.84 in 1953 to 1.01 in 1954. The 1953 accident record is the best in the history of the coal industry. Nonfatal figures for 1954 are incomplete. Whereas Title II of the Federal Coal Mine Safety Act was designed to prevent major disasters in coal mines employing regularly 15 or more persons underground and provided enforcement authority to attain this end, the results of operation under the act apparently extended beyond the scope thereof by stimulating generally the safety efforts of the entire industry during the 2-1/2-year period since its enactment.

The number of major coal-mine disasters in the United States and the fatalities resulting from them are listed for each year since 1931 in table 3 of Appendix K. A major disaster is defined as any accident that causes the death of five or more persons. Two major coal-mine disasters have occurred since the effective date of the Federal Coal-Mine Safety Act. The first of these, which caused the death of five men in 1953, was the result of a coal-dust explosion initiated by a blownout charge of black blasting powder in an Iowa mine. A temporary restraining order issued by a State court prohibited Federal inspectors from enforcing the ban on the use of black blasting powder as provided for in the Federal Coal Mine Safety Act. The other, in November 1954, killed 16 men, 1 on the surface and 15 entombed underground, when a violent explosion followed by a roaring mine fire necessitated sealing the mine surface openings to smother the fire before recovery operations could proceed.

Table 4, Appendix K, gives a comparison of the underground fatality frequency experience in Title I and Title II mines for 1951 through 1954.

Major improvements made in coal mines during the past 13 years contributed much to the favorable decrease in the injury rates. The records show that since December 1941 a systematic roof-support plan has been adopted in 2,475 mines; the use of dangerous black powder was discontinued in 1,624 mines; new main fans were installed at 2,919 mines; auxiliary blower fans with tubing were removed from 586 mines; preshift examinations for gas and other dangers were begun in 3,146 mines; onshift examinations for gas were begun in 2,236 mines; the use of water to allay dust was initiated in 1,028 mines; 1,868 mines were rock-dusted for the first time; second-openings were provided in 936 mines; regulations against smoking were adopted in 1,679 mines; and the use of open lights was discontinued in 1,482 mines. (See Appendix L for details.)

The favorable results attained during the past 13 years are not due to the efforts of any one group or agency, but it is well known in mining circles that Federal coal-mine inspection activities have been, and continue to be, a great influence in giving deserved attention to health and safety in coal mines. The Bureau has striven, with success, to have management and labor work hand-in-hand to iron out their safety and health problems. It is the cooperative efforts of management, labor, State inspection agencies, manufacturers of mining equipment, coal operators' associations, the Federal Bureau of Mines, and other agencies interested in mine safety that have brought about the improvements in conditions and practices that have resulted in continuing reduction in coal-mine injuries.

RECOMMENDATIONS FOR LEGISLATIVE ACTION

It is evident that many hazards that might lead to disasters are being eliminated in the mines that come within the scope of the mandatory provisions of the Federal Coal Mine Safety Act, but much more can be accomplished if the enforcement powers afforded the Federal inspectors were expanded to cover most of the smaller mines - those employing less than 15 men underground - which as a group are poorly regulated. This is born out by the fact that 39 percent of the inspection reports on these mines indicated serious hazards that were not corrected promptly and only 16 percent of all the dangerous conditions reported were being corrected during the period covered by this report. (See Appendix C and Appendix G.) In addition, the underground fatality-frequency rate for mines employing 14 or less men underground, Title I mines, was 4.22 during 1954 compared with 1.01 for mines employing 15 or more men underground, Title II mines. These data are given in Appendix K, table 4.

PUBLICATIONS

The following Bureau of Mines publications, issued during 1954, were prepared wholly or partly by personnel of the Coal-Mine Inspection Branch:

Publication		Title	Authors
HSS	426	Fatalities at Pennsylvania Anthracite Mines, 1953	J. V. Mather
HSS	425	Haulage Fatalities in Bituminous-Coal Mines	D. S. Kingery
HSS	427	Falls of Roof, The No. 1 Killer at Bituminous-Coal Mines	
M.C.	35	Protection Against Mine Gases (1954 Revision)	W. Dan Walker, Jr., and A. E. Morrow
M.C.	49	Accidents from Hoisting and Haulage in Bituminous-Coal Mines - Coal-Mine Accident-Prevention Course, Section 3	D. S. Kingery
M.C.	59	Electrical Accidents in Bituminous-Coal Mines - Coal-Mine Accident-Prevention Course, Section 6	C. L. Brown
I.C.	7678	Roof Bolting in Alabama Coal Mines and Iron-Ore Mines	H. C. Young
I.C.	7685	Administration of the Federal Coal Mine Safety Act	James Westfield, H. F. Weaver, and C. M. Keenan
I.C.	7694	It Couldn't Happen (a description of five unusual fatal accidents)	D. S. Kingery
I.C.	7701	Recommended Standards for Installation and Maintenance of Haulage Roads	T. F. Curry and D. S. Kingery

Publication		Title	Authors
I.C.	7703	Testing for Methane in Out-of-Reach Places	M. L. Davis
I.C.	7708	Coal-Mine Hazards From Overlying Gasoline Pipelines. Descriptions of Gasoline Explosions in Two Pennsylvania Bituminous-Coal Mines	W. Dan Walker, Jr., J. H. Dumire
FSC		Federal Mine Safety Code for Bituminous-Coal and Lignite Mines in the United States. Part I - Underground Mines, October 8, 1953	
FSC		Federal Mine Safety Code for Bituminous-Coal and Lignite Mines in the United States. Part II - Strip Mines, October 8, 1953	

APPENDIX A

Office of the Director A.O. 695

UNITED STATES
DEPARTMENT OF THE INTERIOR
Bureau of Mines
Washington 25, D. C.

December 8, 1954

ADMINISTRATIVE ORDER 695

SUBJECT: Part A - Reorganization of Health and Safety Activities

Part B - Delegation of authority to District Health and Safety Supervisors, Chief, Branch of Health Research, and Chief, Branch of Electrical-Mechanical Testing

PART A

1. The Administrative Assistant Secretary of the Interior, on November 2, 1954, approved the reorganization of the Health and Safety Activities and authorized the Bureau to "proceed with the implementation job necessary to put this organization into effect." The new organization is consistent with the Management Survey Team Report on the Bureau of Mines.

In accordance with the authority quoted above from the Administrative Assistant Secretary, the following changes effective at the beginning of the next pay period (December 19, 1954) are hereby made in the Health and Safety Activities:

GENERAL

.1 Purpose. The nationwide activities of the Bureau of Mines concerned with health and safety in the mineral industries, including education, coal mine inspection, accident statistics, rescue and recovery operations, roof control activities, and mine-fire control projects are carried out through the Office of Assistant Director for Health and Safety. Health research, mining equipment testing and analyses, and educational motion picture activities are also conducted within the Office.

.2 Composition. The Office is composed of headquarters organization in Washington, D. C., and eight district offices, with subdistrict offices thereunder. These offices operate independently of the regional organization of the Bureau, except for administrative services, which are provided by the staffs of the Washington office, Region III, and Region V.

HEADQUARTERS ORGANIZATION

.3 Assistant Director for Health and Safety. The Assistant Director for Health and Safety, subject to the direction of the Director, supervises and coordinates the activities of the Office, and is responsible to the Director for

developing broad objectives, formulating programs, and determining standards of operations. He aids the Director in administering the Federal Coal Mine Safety Act. Staff assistance to the Assistant Director is provided through technical assistants in his immediate office and three divisions, one of which is also responsible for certain centralized operations.

.4 Division of Coal Mine Inspection. The Division of Coal Mine Inspection provides staff assistance in formulating programs for the Assistant Director for Health and Safety, and also basic policies and standards to guide district field offices in carrying out nationwide programs of health and safety inspection and education in the coal-mining industry. It performs these functions by means of field inspections, review of reports, and evaluation of operations based on such inspections and review. The Division also assists the Assistant Director in administering the Federal Coal Mine Safety Act which is designed to prevent major disasters, promote health, and improve safety in coal mines.

.5 Division of Health. The Division of Health provides staff assistance in formulating programs and basic policies in regards to health activities in the mineral industries; including recognition and control of harmful or hazardous exposures, improvement of hygienic conditions, hygienic aspects of exposure to dusts, fumes, and gases in connection with the mining, preparation and utilization of minerals substances; also, investigation of atmospheric health hazards and ventilation requirements necessary to their control at mines and plants and in connection with industrial equipment; formulation of standards of allowable concentrations of atmosphere contaminants; development of standards and schedules under which respiratory protective devices and gas-detection devices are tested and approved for safe use in mineral industries; analysis of air and gas samples taken in connection with safety inspection of mines and plants, and the testing of respiratory protective devices for permissibility.

A. The Branch of Health Research. Located at Pittsburgh, Pennsylvania, the Branch of Health Research conducts research and testing as required to carry out the program of the Division, which is above described. Research and analytical activities for the western district offices are conducted at Denver, under the supervision of this Branch.

.6 Division of Safety. The Division of Safety provides staff assistance for plans and coordination of the Bureau's programs concerned with safety and education in the mineral industries, other than coal, on accident statistics, rescue and recovery operations after mine fires and explosions, and for roof control work in both the coal and metal-mining industries and control of underground and outcrop fires in inactive coal deposits. The Division plans and formulates programs for investigating safety conditions in the mineral industries and makes public reports on these conditions, with recommendations for eliminating hazards; recommends assignments of activities to the field offices to carry out approved programs, establishes standards of performance by the field offices, prepares progress reports to reflect performance, and, after analysis of these reports, recommends to the Assistant Director action necessary to strengthen and improve field operations. Provides consultative services to Government agencies and to industry and labor groups on accident statistics.

A. The Branch of Accident Analyses. Collects data on, and conducts analytical studies of, frequency, severity, location, cause, and other factors pertaining to fatal and nonfatal injuries in the mineral industries, and publishes statistics thereon. It provides basic accident data in connection with,

and conducts, the annual safety competitions in the mineral industries. The Branch also collects and publishes data on the consumption of explosives used in the mineral industries.

B. The Branch of Electrical-Mechanical Testing. Located at Pittsburgh, Pennsylvania, is responsible for conducting research in the various factors affecting safety of life and property in the design, installation, and use of equipment and electrical circuits in mines and plants of the mineral industries and in installations of Government defense agencies. It performs similar activities in connection with diesel-driven equipment in mines, including approval testing of such equipment. The Branch cooperates with manufacturers, management, and labor in improving the safety design of mining equipment.

FIELD ORGANIZATION

.7 District Offices. There are eight district offices, each under the direction of a District Health and Safety Supervisor who is responsible directly to the Assistant Director for Health and Safety. Each district office carries on within its geographic area the approved inspection, education, and other related programs, through planning, directing, and reviewing the work of its staff engineers, coal mine inspectors, safety workers, and instructors. The district office serves as principal program administrator of the Federal Coal Mine Safety Act, and carries out health and safety educational and first-aid training operations. Mine-fire control work is conducted in Districts A, B, and H; however, such work within the geographic area of District A is conducted by the Anthracite Research Laboratory at Schuylkill Haven, Pennsylvania and reports to the headquarters office in Washington, D. C. Administrative services for District A and Schuylkill Haven, Pennsylvania are provided by the Administrative Division of the Bureau headquarters organization at Washington, D. C.; for Districts B, C, D, E, F, and G, by the Administrative Division, Region V, Pittsburgh, Pennsylvania; and for District H, by the Administrative Division, Region III, Denver.

.8 Subdistrict Offices. To assist the District Health and Safety Supervisor in carrying out the programs of his geographic area, also, in order to locate health, safety, and coal mine inspection personnel near the actual field of operations there are subdistrict offices, each under the direction of a Subdistrict Health and Safety Supervisor, who reports to the District Health and Safety Supervisor.

.9 Location of Field Offices. The boundaries and headquarters of the district offices and the location of subdistrict offices thereunder, with Mine Fire Control and certain Coal Mine inspection responsibilities are indicated below:

District A: Pennsylvania (east of a north-south line through Harrisburg), Maine, New Hampshire, Vermont, Massachusetts, New York, Rhode Island, Connecticut, Delaware, and New Jersey.
Headquarters: Wilkes-Barre, Pennsylvania.
Subdistrict Office: Albany, New York.
Mine Fire Control operations for District A are conducted by the Anthracite Research Laboratory, Schuylkill Haven, Pennsylvania.

District B: Pennsylvania (west of a north-south line through Harrisburg, Pennsylvania), Ohio, and the West Virginia counties of Marshall, Ohio, Brooke, and Hancock.

Headquarters: Pittsburgh, Pennsylvania.
Subdistrict Offices: Johnstown, Pennsylvania; St. Clairsville, Ohio.
This district is responsible for Mine Fire Control operations in Districts B, C, D, and E.

District C: West Virginia (except the counties of Marshall, Ohio, Brooke and Hancock), Maryland, Virginia, and that portion of Kentucky east of a line extending south from the Indiana-Ohio boundary through Frankfort, Kentucky, to Tennessee.
Headquarters: Mt. Hope, West Virginia.
Subdistrict Offices: Morgantown, West Virginia; Norton, Virginia; and Barbourville, Kentucky.

District D: North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, and Tennessee.
Headquarters: Birmingham, Alabama.
Subdistrict Office: Jellico, Tennessee.

District E: Indiana, Illinois, portion of Kentucky (west of a line extending south from the Indiana-Ohio boundary through Frankfort, Kentucky, to Tennessee), Missouri, and Iowa.
Headquarters: Vincennes, Indiana.

District F: North Dakota, South Dakota, Nebraska, Minnesota, Wisconsin, and Michigan.
Headquarters: Duluth, Minnesota.

District G: Texas, Oklahoma, Kansas, Arkansas, and Louisiana.
Headquarters: Dallas, Texas.
Subdistrict Office: McAlester, Oklahoma.

District H: Colorado, Arizona, New Mexico, Washington, Idaho, Montana, Oregon, Wyoming, California, Nevada, Utah, and the Territory of Alaska.
Headquarters: Denver, Colorado.
Subdistrict Offices: Anchorage, Alaska; Seattle, Washington; Salt Lake City, Utah; Phoenix, Arizona; and San Francisco, California. This district is responsible for Mine Fire Control operations in Districts F, G, and H; and, also, for Coal Mine Inspection in North Dakota and South Dakota.

II. The following principal officials in the Health and Safety Activities are hereby designated:

Assistant Director - James Westfield
Chief, Division of Coal-Mine inspection - Harry F. Weaver
Chief, Division of Health - James Westfield
Chief, Branch of Health Research - Lawrence B. Berger
Chief, Division of Safety - William J. Fene
Chief, Branch of Electrical-Mechanical Testing - Ernest J. Gleim
Chief, Branch of Accident Analysis - Seth T. Reese

The District Supervisors of Health and Safety are listed below:

Edward H. McCleary - District A
W. Dan Walker - District B
William R. Park - District C

Milton C. McCall - District D
Eugene E. Quenon - District E
John A. Johnson - District F
George M. Kintz - District G
J. Howard Bird - District H

III. Revocations. (1) The present Health and Safety Division and its branches and sections headquartered at Washington, D. C. are hereby abolished and the personnel transferred to other units.

(2) The present Accident-Prevention and Health Divisions in Regions I through VIII are hereby abolished and the present staff of those divisions are transferred for management purposes to the District offices which are established in this order.

(3) All authorities previously delegated to Regional Directors of Regions I-VIII, inclusive pertaining to the Health and Safety Activities are hereby revoked, except such administrative functions as are covered in Administrative Order 693 dated November 22, 1954.

APPENDIX B

TABLE 1. - Details of inspection data - Title II mines - 1954

States	Title II mine inspections	Joint State-Federal inspections 1/	Violations Sec. 209 observed	Mines at which Form B notices were issued	Notices issued: Form B (original)	Notices issued: Form C: Violations abated	Notices issued: Form C: Time extended	Orders issued: Form A 203(a)	Orders issued: Form D 203(c)	Orders issued: Form B-1 203(d)	Mines at which orders were issued: Form A	Mines at which orders were issued: Form D	Mines free of violations of Title II	Title II mines inspected
Alabama	107	0	40	9	30	30	6	0	2	1	0	1	28	42
Alaska	5	4	7	1	4	4	0	0	0	0	0	0	0	2
Arizona	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arkansas	24	0	47	3	17	17	1	2	0	0	1	0	5	7
California ...	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colorado	53	0	94	16	37	36	0	0	0	0	0	0	6	22
Georgia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idaho	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Illinois	167	0	340	48	136	151	34	11	5	3	7	3	33	63
Indiana	41	0	128	19	88	100	15	2	2	0	2	1	2	16
Iowa	13	0	1	1	1	1	0	0	0	0	0	0	6	7
Kansas	5	0	3	0	0	0	0	2	0	0	1	0	2	2
Kentucky	690	0	1,346	197	681	678	67	6	26	4	6	14	88	303
Maryland	7	0	5	1	1	1	0	0	0	0	0	0	1	3
Michigan	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Missouri	33	0	3	0	0	0	0	0	0	0	0	0	9	9
Montana	10	0	3	0	0	0	0	0	0	0	0	0	4	3
New Mexico ...	4	0	3	0	0	0	0	0	0	0	0	0	1	2
North Carolina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North Dakota..	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ohio	127	0	218	28	74	75	11	0	0	1	0	0	5	46
Oklahoma	18	18	16	2	5	5	1	0	0	0	0	0	4	6
Oregon	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pennsylvania (anthracite).	402	0	230	59	126	113	92	6	2	0	5	2	111	138
Pennsylvania (bituminous).	590	0	1,039	118	286	279	53	5	10	2	4	3	85	223
Tennessee	59	0	173	23	85	84	46	4	6	1	3	4	11	29
Texas	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Utah	55	0	80	8	11	10	1	0	0	0	0	0	13	20
Virginia	256	0	589	81	328	331	18	6	5	3	2	1	29	103
Washington ...	21	21	15	5	10	10	0	0	0	0	0	0	1	8
West Virginia.	1,190	0	3,602	324	1,013	1,029	307	14	18	3	12	9	108	437
Wyoming	17	17	30	0	0	1	0	0	0	0	0	0	2	7
Totals	3,894	60	8,012	943	2,933	2,955	652	58	76	2/18	43	38	554	1,498

1/ Included in Title II mine inspections.
2/ One order annulled by the Director.

APPENDIX B (Con.)

TABLE 2. - Withdrawal orders issued under Sec. 203(a) for imminent danger, by States, July 16, 1952 - December 31, 1954

Conditions constituting imminent danger	Alaska	Arkansas	Colorado	Illinois	Indiana	Kansas	Kentucky	Oklahoma	Pennsylvania (anthracite)	Pennsylvania (bituminous)	Tennessee	Virginia	West Virginia	Total
Man-trip:														
Dangerous roof	1	-	-	2	-	-	-	-	-	2	3	9	7	24
Poor track and equipment	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Man-hoist:														
Worn rope	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Shaft partition and cages deteriorated	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Mine fire:														
Active fire adjacent to producing area	1	-	-	-	-	-	-	-	1	-	-	-	1	3
Electric-arc hazards and accumulated coal and coal dust	-	1	-	1	-	-	3	-	-	-	-	-	-	5
Poor electrical installation ...	-	-	-	1	-	1	-	-	-	-	-	2	1	5
Loose coal, inadequate ventilation, open oil containers	-	-	-	-	-	-	1	-	-	-	-	1	-	2
Mine explosion:														
Excessive methane liberations ..	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Methane and dust accumulations..	-	-	-	3	1	-	-	1	-	-	-	-	1	6
Methane accumulations	-	-	-	1	-	1	-	-	10	-	-	-	1	13
Leak in surface gasoline line ..	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Inadequate rock dusting	-	-	-	-	-	-	-	-	-	1	-	-	4	5
Coal-dust accumulations, no rock dust, and poor ventilation ...	-	1	-	6	-	-	-	-	-	-	-	2	6	15
Active mine fire	-	-	-	-	1	-	1	-	1	-	-	-	-	3
Black powder and inadequate rock dust	-	-	-	1	-	-	-	-	-	-	-	-	-	1
Explosion disrupted ventilation.	-	-	-	-	-	-	-	-	-	1	-	-	1	2
Coal-dust stemming, no tests for gas, doors open	-	-	-	-	-	-	-	-	-	-	2	-	-	2
Inundation:														
Working under body of water	-	-	-	-	-	-	2	-	-	-	-	-	-	2
Advancing toward abandoned workings	-	-	-	-	-	-	-	-	1	-	1	1	-	3
Inflow of oxygen-deficient air..	-	-	-	1	-	-	-	-	-	-	-	1	-	2
Total	2	2	2	16	2	2	7	1	13	6	6	16	23	98

APPENDIX B (Con.)

TABLE 3. - Withdrawal orders issued under Sec. 203(c) for failure to abate violations of Sec. 209, by States July 16, 1952 - December 31, 1954

Sections violated	Alabama	Arkansas	Illinois	Indiana	Iowa	Kentucky	Missouri	Ohio	Pennsylvania (anthracite)	Pennsylvania (bituminous)	Tennessee	Utah	Virginia	West Virginia	Total
209(c)	-	-	-	-	-	4	-	-	-	2	-	-	1	7	14
209(d)(1)	2	1	1	-	-	13	1	1	3	6	2	-	6	4	40
209(d)(6)	-	-	3	-	-	1	-	-	-	1	-	-	-	3	8
209(d)(8)	-	-	-	-	-	11	-	1	-	-	-	-	1	-	13
209(d)(9)	-	-	1	1	-	2	-	-	-	-	-	-	-	2	6
209(e)(1)	-	-	2	-	-	18	-	-	-	2	1	-	12	10	45
209(e)(3)	-	-	1	1	4	10	-	1	-	3	1	-	6	5	32
209(e)(4)	-	-	-	-	-	5	-	-	-	1	-	-	-	2	8
209(e)(5)	-	-	-	1	-	16	-	-	-	2	2	-	11	7	39
209(f)(1)	-	-	-	-	-	1	-	-	-	2	-	-	-	1	4
209(g)(1)	-	-	1	-	-	2	-	-	-	1	-	-	2	5	11
209(g)(5)	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
209(h)(2)	-	-	-	-	-	-	-	-	-	-	-	1	-	1	2
209(h)(5)	-	-	2	-	2	-	-	-	-	-	-	-	-	-	4
Total ...	2	1	12	3	6	83	1	3	3	20	6	1	39	47	227

APPENDIX C

Data pertaining to serious hazards observed

State	Title I mines: Title I inspections	Title I mines: Serious hazard letters sent to State Agency	Title I mines: Percent of inspections revealing serious hazards	Title II mines: Title II inspections	Title II mines: Serious hazard letters sent to State Agency	Title II mines: Percent of inspections revealing serious hazards
Alabama	653	233	36	107	6	6
Alaska	3	1	33	5	0	0
Arizona	11	0	0	0	0	-
Arkansas	23	19	83	24	11	46
California	0	0	-	0	0	-
Colorado	257	27	11	53	0	0
Georgia	10	5	50	0	0	-
Idaho	1	0	0	0	0	-
Illinois	130	85	65	167	65	39
Indiana	82	41	50	41	8	20
Iowa	87	23	26	13	1	8
Kansas	16	6	38	5	4	80
Kentucky	1,083	448	41	690	43	6
Maryland	72	29	40	7	1	14
Michigan	0	0	-	0	0	-
Missouri	48	37	77	33	13	39
Montana	118	58	50	10	0	0
New Mexico	103	5	5	4	0	0
North Carolina.	0	0	-	0	0	-
North Dakota ..	21	1	5	0	0	-
Ohio	462	202	44	127	18	14
Oklahoma	25	12	48	18	5	28
Oregon	4	2	50	0	0	-
Pennsylvania (anthracite)..	650	53	8	402	16	4
Pennsylvania (bituminous)..	520	163	31	590	48	8
Tennessee	722	313	43	59	7	12
Texas	0	0	-	0	0	-
Utah	91	71	78	55	7	13
Virginia	738	507	69	256	13	5
Washington	19	9	47	21	1	5
West Virginia..	635	208	33	1,190	140	12
Wyoming	41	14	34	17	3	18
National data..	6,625	2,572	39	3,894	410	11

APPENDIX D

Appeals to the Director under Sec. 206(c) and appeals to the Federal Coal Mine Safety Board of Review under Sec. 207 July 16, 1952 - December 31, 1954

Mine and company	Reason for appeal	Disposition by: Director	Disposition by: Board
Maxton Slope mine, Morrisdale Mining Co., Hawk Run, Pa.	Gassy classification 203(d).		Appeal denied 10/18/52.
Glenmar No. 1 mine, Moshannon-Smithing Coal Co., Beccaria, Pa.	do.	Appeal denied 12/31/52.	Appeal denied 2/24/53.
Ponfeigh Pine Hill mine, Ponfeigh Pine Hill Smokeless Coal Co., Garrett, Pa.	do.	Order annulled 3/2/53. Field investigation 12/8/52.	
Seaboard No. 1 mine, Rebecca Coal Co., Richlands, Va.	do.	Appeal denied 6/16/53.	Appeal made 7/8/53. Hearing 11/10-11/53. Annulled 12/3/53.
Carnegie mine, Clean Coal Co., Bellaire, Ohio	do.	Appeal denied (application not made within 20 days).	
Haws No. 7 mine, Haws Refractories Co., Johnstown, Pa.	do.	Appeal denied 8/10/53.	
Kleaner No. 1 mine, Kleaner Coal Co., Bokoshe, Okla.	Imminent explosion danger.		1/Appeal made 9/27/53. Hearing 10/2/53. Annulled 10/2/53.
Talleydale mine, Snow Hill Coal Corp., Terre Haute, Ind.	2/ Violation of Sec. 209(d)(9)	Order annulled 8/4/53.	Appeal made for temporary relief 6/5/53. Hearing 6/17/53-time extended for total abatement until 7/11/53.

1/ State-participation plan in effect.
2/ Failure to make tests for gas before electrical equipment taken beyond the last open crosscut.

Mine and company	Reason for appeal	Disposition by: Director	Board
Princess No. 2, Princess Elkhorn Coal Co., Permele, Ky.	Gassy classification Sec. 203(d).	Order annulled 2/11/54.	
Do.	do.	Denied 10/15/54.	Appeal made 11/3/54. Hearing 11/30/54 and 12/10/54. Order annulled 1/28/55.
Cassity mine, Nos. 2, 3, and 6 openings, Three Fork Coal Co., Inc., Cassity, W. Va.	3/Violation of Sec. 209(e)(1).		Appeal made 12/13/54. Granted temporary relief through 1/17/55. Full hearing 1/17/55 to 1/20/55 granted temporary relief pending decision.

3/ Dangerous accumulation of loose coal and coal dust.

APPENDIX E

TABLE 1. - Number of active coal mines in the Nation - 1954

State	Title I mines: Strip	Title I mines: Underground	Title I mines	Title II mines	Total mines
Alabama	20	383	403	42	445
Alaska	3	1	4	2	6
Arizona	0	4	4	0	4
Arkansas	3	15	18	7	25
California	0	0	0	0	0
Colorado	6	132	138	22	160
Georgia	0	9	9	0	9
Idaho	0	1	1	0	1
Illinois	44	83	127	83	210
Indiana	44	35	79	20	99
Iowa	29	33	62	7	69
Kansas	10	4	14	2	16
Kentucky	76	1,144	1,220	303	1,523
Maryland	15	44	59	4	63
Michigan	0	0	0	0	0
Missouri	11	24	35	9	44
Montana	35	47	82	3	85
New Mexico	7	47	54	2	56
North Carolina ..	0	0	0	0	0
North Dakota	22	3	25	0	25
Ohio	106	203	309	46	355
Oklahoma	11	13	24	6	30
Oregon	0	3	3	0	3
Pennsylvania (anthracite) ...	158	560	718	138	856
Pennsylvania (bituminous) ...	463	501	964	226	1,190
Tennessee	67	766	833	29	862
Texas	0	0	0	0	0
Utah	0	36	36	20	56
Virginia	20	793	813	103	916
Washington	4	8	12	8	20
West Virginia ...	110	607	717	481	1,198
Wyoming	11	16	27	7	34
Total	1,275	5,515	6,790	1,570	8,360

APPENDIX E (Con.)

TABLE 2. - Number of regular inspections, surveys, and investigations of disasters and fatal accidents since 1941

Period	Field headquarters	Inspections			Surveys				Investigations of fatalities and disasters
		Original	Reinspections	Total	Electrical	Explosives	Ventilation	Dust	
1941-1953	All	13,430	48,617	62,047	223	248	29	40	2,143
1954	Anchorage	1	7	8	0	0	0	0	3
	Seattle	11	162	173	0	0	0	0	3
	Denver	8	351	359	12	0	0	0	3
	Salt Lake City	2	183	185	9	0	0	0	9
	Phoenix	8	80	88	0	0	0	0	0
	Duluth	12	109	121	0	0	0	0	0
	McAlester	7	185	192	1	0	0	0	1
	Birmingham	102	668	770	0	0	0	0	12
	Jellico	329	452	781	27	0	1	0	17
	Pittsburgh	47	429	476	14	0	1	0	41
	Johnstown	57	577	634	0	0	1	0	29
	St. Clairsville	115	510	625	1	0	0	0	13
	Morgantown	67	622	689	17	0	0	0	37
	Mt. Hope	184	995	1,179	14	0	0	0	109
	Norton	449	1,130	1,579	1	0	0	0	40
	Barbourville	296	724	1,020	5	0	0	0	39
	Vincennes	18	570	588	3	0	2	0	62
	Wilkes-Barre	275	777	1,052	0	0	0	0	101
Totals 1954		1,988	8,531	10,519	104	0	5	0	519
Grand Totals		15,418	57,148	72,566	327	248	34	40	2,662

APPENDIX E (Con.)

TABLE 3. - Mines inspected, regular inspections, and average inspections per active mine - 1954

State	Mines inspected				Inspections made				Average inspections per active mine			
	A	B	C	Total	A	B	C	Total	A	B	C	Total
Alabama	20	313	42	375	32	621	107	760	1.6	1.6	2.5	1.7
Alaska	2	1	2	5	2	1	5	8	.7	1.0	2.5	1.3
Arizona	0	4	0	4	0	11	0	11	0	2.8	0	2.8
Arkansas	3	13	7	23	3	20	24	47	1.0	1.3	3.4	1.9
California	0	0	0	0	0	0	0	0	-	-	-	-
Colorado	4	132	22	158	4	253	53	310	.7	1.9	2.4	1.9
Georgia	0	6	0	6	0	10	0	10	-	1.2	-	1.2
Idaho	0	1	0	1	0	1	0	1	-	1.0	-	1.0
Illinois	40	58	63	161	40	90	167	297	.9	1.1	2.0	1.4
Indiana	39	29	16	84	39	43	41	123	.9	1.2	2.0	1.2
Iowa	25	30	7	62	25	62	13	100	.9	1.9	1.8	1.4
Kansas	10	4	2	16	10	6	5	21	1.0	1.5	2.5	1.3
Kentucky	37	828	303	1,168	38	1,045	690	1,773	.5	.9	2.3	1.2
Maryland	8	34	3	45	8	64	7	79	.5	1.5	1.7	1.3
Michigan	0	0	0	0	0	0	0	0	-	-	-	-
Missouri	10	21	9	40	10	38	33	81	.9	1.6	3.7	1.8
Montana	26	45	3	74	38	80	10	128	1.1	1.7	3.3	1.5
New Mexico	7	47	2	56	9	94	4	107	1.3	2.0	2.0	1.9
North Carolina..	0	0	0	0	0	0	0	0	-	-	-	-
North Dakota ...	19	1	0	20	19	2	0	21	.9	.7	-	.8
Ohio	106	199	46	351	106	356	127	589	1.0	1.8	2.8	1.7
Oklahoma	9	10	6	25	9	16	18	43	.8	1.2	3.0	1.4
Oregon	0	3	0	3	0	4	0	4	-	1.3	-	1.3
Pennsylvania (anthracite) ..	38	461	138	637	39	611	402	1,052	.2	1.1	2.9	1.2
Pennsylvania (bituminous) ..	23	352	223	598	23	497	590	1,110	.1	1.0	2.6	.9
Tennessee	56	576	29	661	59	663	59	781	.9	.9	2.0	.9
Texas	0	0	0	0	0	0	0	0	-	-	-	-
Utah	0	36	20	56	0	91	55	146	-	2.5	2.7	2.6
Virginia	0	604	103	707	0	738	256	994	0	.9	2.5	1.1
Washington	4	8	8	20	4	15	21	40	1.0	1.9	2.6	2.0
West Virginia ..	20	461	437	918	20	615	1,190	1,825	.2	1.0	2.5	1.5
Wyoming	11	16	7	34	14	27	17	58	1.3	1.7	2.4	1.7
National data ..	517	4,293	1,498	6,308	551	6,074	3,894	10,519	.4	1.1	2.5	1.3

A - Strip mines.
B - Title I underground mines.
C - Title II mines.

APPENDIX E (Con.)

TABLE 4. - Average man-days to complete regular inspections and reports

States	Title I mines				Title II mines		All mines	
	Strip		Underground					
	A	B	A	B	A	B	A	B
Alabama	1.0	0.4	0.8	0.5	3.6	0.5	1.2	0.5
Alaska	1.0	1.0	1.0	1.0	1.6	.6	1.4	.8
Arizona	-	-	1.3	.6	-	-	1.3	.6
Arkansas	2.0	1.0	1.7	1.1	3.3	1.1	2.6	1.1
California	-	-	-	-	-	-	-	-
Colorado	1.7	.7	1.2	.7	3.1	.8	1.6	.7
Georgia	-	-	.7	.5	-	-	.7	.5
Idaho	-	-	9.0	1.0	-	-	9.0	1.0
Illinois	1.5	.5	1.7	.7	5.3	.8	3.7	.7
Indiana	1.0	.5	1.2	.8	4.1	1.2	2.1	.8
Iowa	.8	.5	1.5	.7	1.2	.7	1.3	.6
Kansas	1.2	.7	1.7	.8	2.5	1.0	1.7	.8
Kentucky	1.1	.9	1.0	.8	2.8	.8	1.7	.8
Maryland	.6	.7	.6	.8	1.3	.9	.7	.8
Michigan	-	-	-	-	-	-	-	-
Missouri	1.6	.9	1.3	.8	2.0	.8	1.7	.8
Montana	.8	.4	.9	.6	2.8	1.0	1.0	.6
New Mexico	1.1	.5	1.0	.7	2.0	1.0	1.1	.7
North Carolina	-	-	-	-	-	-	-	-
North Dakota	1.7	.5	2.0	1.0	-	-	1.8	.6
Ohio	1.2	.8	1.1	.9	3.4	.9	1.6	.9
Oklahoma	1.0	.8	1.4	1.6	4.8	1.1	2.7	1.2
Oregon	-	-	2.0	.7	-	-	2.0	.7
Pennsylvania (anthracite)	.6	.5	1.0	.9	5.5	.9	2.7	.9
Pennsylvania (bituminous)	.9	.8	.9	1.1	4.3	1.1	2.7	1.1
Tennessee	.5	.5	.7	.7	3.7	1.0	.9	.7
Texas	-	-	-	-	-	-	-	-
Utah	-	-	1.1	.4	4.1	.5	2.2	.5
Virginia	-	-	1.0	.9	2.3	1.0	1.3	.9
Washington	1.0	.7	1.3	.6	3.9	.7	2.6	.7
West Virginia	1.0	.7	.8	.7	3.5	.8	2.6	.8
Wyoming	1.5	.6	1.1	.6	3.6	.6	1.9	.6
National data	1.0	.6	1.0	.8	3.7	.9	2.0	.8

A - Average days to complete regular inspection. Includes inspection, travel, preparing, and posting preliminary report or notices or orders, conference with mine personnel, and preparing notes and sampling cards.

B - Average days for inspector to prepare rough draft of final inspection report.

APPENDIX E (Con.)

TABLE 5. - Special inspections and average total time to complete inspection under Title II

Field Office	Special inspections	Man-days making special inspections: Total	Man-days making special inspections: Average per special inspection	Regular inspections, Title II mines	Average additional man-days per regular inspection	Average man-days per regular inspection	Average total time per Title II inspection
Anchorage	2	2	1.0	5	0.4	1.5	1.9
Seattle	7	21	3.0	31	.7	3.5	4.2
Denver	33	38	1.2	56	.7	3.1	3.8
Salt Lake City..	12	12	1.0	72	.2	3.9	4.1
Phoenix	0	0	0	1	0	.9	.9
Duluth	1	1	1.0	13	.1	1.2	1.3
McAlester	14	44	3.1	80	.6	3.1	3.7
Birmingham	30	31	1.0	107	.3	3.6	3.9
Jellico	100	79	.8	59	1.3	3.7	5.0
Pittsburgh	90	97	1.1	286	.3	4.8	5.1
Johnstown	169	177	1.0	304	.6	3.9	4.5
St. Clairsville.	70	59	.8	142	.4	3.6	4.0
Morgantown	173	171	1.0	317	.5	3.1	3.6
Mt. Hope	935	935	1.0	865	1.1	3.6	4.7
Norton	354	282	.8	468	.6	2.6	3.2
Barbourville....	297	249	.8	374	.7	2.8	3.5
Vincennes	267	273	1.0	312	.9	4.3	5.2
Wilkes-Barre ...	173	174	1.0	402	.4	5.5	5.9
National data inspection work	2,727	2,645	1.0	3,894	.7	3.7	4.4
Average time to write inspection report....							.9
Total average time Title II mine							5.3

APPENDIX F

Violations of the Federal Mine Safety Codes

State	Title I mines				Title II mines			
	Mines inspected	Violations reported 1/	Average violations per mine inspected	Mines free of violations	Mines inspected	Violations reported 1/	Average violations per mine inspected	Mines free of violations
Alabama	333	7,267	22	1	42	300	7	12
Alaska	3	51	17	0	2	30	15	0
Arizona	4	34	9	0	0	-	-	-
Arkansas	16	545	34	0	7	204	29	0
California ...	0	-	-	-	0	-	-	-
Colorado	136	1,057	8	1	22	234	11	3
Georgia	6	149	25	0	0	-	-	-
Idaho	1	5	5	0	0	-	-	-
Illinois	98	1,272	13	0	63	1,272	20	0
Indiana	68	716	11	1	16	297	19	0
Iowa	55	884	16	0	7	126	18	0
Kansas	14	257	18	0	2	67	33	0
Kentucky	865	18,848	22	0	303	5,136	17	9
Maryland	42	1,130	27	0	3	88	29	0
Michigan	0	-	-	-	0	-	-	-
Missouri	31	698	23	0	9	220	24	0
Montana	71	428	6	9	3	15	5	1
New Mexico ...	54	289	5	1	2	17	8	0
North Carolina	0	-	-	-	0	-	-	-
North Dakota..	20	96	5	0	0	-	-	-
Ohio	305	7,151	23	1	46	1,127	25	0
Oklahoma	19	286	15	0	6	63	10	2
Oregon	3	20	7	0	0	-	-	-
Pennsylvania (anthracite).	499	4,682	9	4	138	1,244	9	7
Pennsylvania (bituminous).	375	6,443	17	3	223	3,610	16	14
Tennessee	632	12,194	19	0	29	719	25	0
Texas	0	-	-	-	0	-	-	-
Utah	36	433	12	2	20	209	10	3
Virginia	604	14,922	25	0	103	1,909	19	3
Washington ...	12	86	7	0	8	75	1	0
West Virginia.	481	11,383	24	0	437	13,067	30	9
Wyoming	27	191	7	1	7	84	12	2
National data.	4,810	91,517	19	24	1,498	30,113	20	65

1/ Includes all violations found during first inspections made during the year and all new violations found during subsequent inspections.

APPENDIX G

Percent of compliance with recommendations of Federal inspectors on violations of the Federal Mine Safety Codes

State	7/1/51 to 6/30/52	7/1/52 to 12/31/52 Title I	1953 Title I	1953 Title II	1954 Title I	1954 Title II
Alabama	13	7	8	63	9	32
Alaska	26	0	17	62	9	60
Arizona	50	0	26	-	47	-
Arkansas	8	-	10	62	14	55
California	-	-	-	-	-	-
Colorado	50	35	53	62	55	75
Georgia	6	4	2	-	11	-
Idaho	-	-	-	-	0	-
Illinois	20	17	23	34	31	48
Indiana	23	22	25	40	31	52
Iowa	7	11	14	21	16	22
Kansas	10	2	16	52	19	33
Kentucky	25	7	12	40	11	38
Maryland	25	19	10	16	22	36
Michigan	27	-	-	-	-	-
Missouri	9	4	13	30	34	60
Montana	25	15	13	48	11	83
New Mexico	49	19	52	50	40	20
North Carolina	38	-	-	-	-	-
North Dakota	24	31	20	33	27	-
Ohio	19	16	22	40	26	60
Oklahoma	18	8	14	57	16	67
Oregon	32	-	9	-	14	-
Pennsylvania (anthracite)	29	17	14	39	18	51
Pennsylvania (bituminous)	37	29	24	56	29	70
Tennessee	14	9	9	38	8	56
Texas	-	-	-	-	-	-
Utah	47	27	33	90	47	77
Virginia	19	7	8	40	5	47
Washington	28	14	16	33	27	35
West Virginia	40	17	18	47	21	52
Wyoming	40	19	25	89	34	65
National average	27	13	15	46	16	52

APPENDIX H

TABLE 1. - Title I mines at which no violations of the Federal Mine Safety Codes were observed during an inspection

1954		
State	Mine	Company
Alabama	Sayre1/	Republic Steel Corp.
Colorado	New Castle	New Castle Coal Co.
Indiana	St. Mary's	Sisters of Providence Coal Co.
Montana	Peuse1/	Gordon Peuse, Operator
Do.	Rosebud Open pit1/	Foley Bros., Inc.
Do.	Wolf Creek1/	T. W. and C. A. Danielson
Do.	Topp1/	Joseph Topp, Operator
Do.	Erickson1/	Theo. Erickson, et al, licensees and operators
Do.	Hanson1/	Perry Hanson, et al, licensees and operators
Do.	New Black Diamond	Ray Duncan, Lessee
Do.	Crow Rock	Fred Hout, lessee and operator
Do.	Brophy	Brophy Coal Co.
New Mexico	Speratos	Albuquerque and Cerrillos Coal Co.
Ohio	Bradford No. 11/	The Hanna Coal Co.
Pennsylvania....	Pittshaw No. 151/	Maral Co.
Do.	Pittshaw No. 16A1/	Do.
Do.	Pittshaw No. 85	Do.
Do.	No. 91 slope	Steve J. Bilko Coal Co.
Do.	Prospect colliery	Lehigh Valley Coal Co.
Do.	No. 1 slope	Springfield Coal Co.
Do.	No. 1 drift	Do.
Utah	Deseret	Deseret Coal Co., cooperative security
Do.	Book Cliffs	Book Cliffs Coal Co.
Wyoming	Blue Diamond1/	Blue Diamond Coal Co.

1/ Strip mines.

APPENDIX H (Con.)

TABLE 2. - Title II mines at which no violations of the Federal Mine Safety Codes were observed during an inspection

State	Mine	Company
1954		
Alabama	*Maxine	Alabama By-Products Corp.
Do.	*Labuco	Do.
Do.	*Gorgas No. 3	Alabama Power Co.
Do.	*Sayre	Republic Steel Corp.
Do.	*Sayreton No. 1	Do.
Do.	*Sayreton No. 2	Do.
Do.	*Hamilton	Tennessee Coal & Iron Division of U. S. Steel Corp.
Do.	*Docena	Do.
Do.	Short Creek No. 19	Do.
Do.	*Concord No. 1	Do.
Do.	*Edgewater	Do.
Do.	*Dolomite No. 3	Woodward Iron Co.
Colorado	*Eagle	Imperial Coal Co.
Do.	*Hawk's Nest	Champion Coal Mining Co.
Do.	*Morley	Colorado Fuel & Iron Corp.
Kentucky	*Hendrix	Consolidation Coal Co.
Do.	*No. 204	Do.
Do.	*No. 214	Do.
Do.	*Pond Creek	Norfolk & Western Railway (Fuel Dept.)
Do.	*Thacker No. 5	Do.
Do.	*Winifrede No. 2	Do.
Do.	*Republic No. 4	Republic Steel Corp.
Do.	*Republic D	Do.
Do.	*High Splint No. 1 Glenbrook colliery	Stonega Coke and Coal Co.
Montana	*Keene No. 2	Mountain States Mining Co.
Oklahoma	*Carbon No. 5	Lone Star Steel Co.
Do.	*McCurtain	Do.
Pennsylvania	*Bridgeport	U. S. Steel Corp.
Do.	*Collier	Do.
Do.	Foster #6 and 8	Leechburg Mining Co.
Do.	*Harwick	Duquesne Light Co.
Do.	*Indianola	Republic Steel Corp.
Do.	*Isabella	Weirton Coal Co.
Do.	*Karen	U. S. Steel Corp.
Do.	*Leisenring No. 2	U. S. Steel Corp.
Do.	*Leisenring No. 3	Do.
Do.	*Maxwell	Do.
Do.	Palmer	Do.
Do.	*Poland No. 1	Molnar Bros. Coal Co.
Do.	*Russellton	Republic Steel Corp.
Do.	*Springdale	Allegheny Pittsburgh Coal Co.
Do.	*No. 10 slope	Ardoline Coal Co.
Do.	*Kirmar slope	Biscontini and Sons Coal Co.
Do.	*No. 58 slope	Do.
Do.	*No. 1 slope	Newport Excavating Co.
Do.	*No. 2A slope	Do.

*Mines appear in both tables 2 and 3.

APPENDIX H (Con.)

TABLE 2. - Title II mines at which no violations of the Federal Mine Safety Codes were observed during an inspection (Con.)

1954		
State	Mine	Company
Pennsylvania (Con.).	*No. 1A slope	Newport Excavating Co.
Do.	*Glen Lyon colliery	Susquehanna Collieries Division The M. A. Hanna Co.
Utah	*Sunnyside No. 2	Kaiser Steel Corp.
Do.	*Sunnyside No. 3	Do.
Do.	*Book Cliffs	Book Cliffs Coal Co.
Virginia	*Moss No. 2	Clinchfield Coal Corp.
Do.	*Moss No. 3	Do.
Do.	*Crossbrook	Stonega Coke and Coal Co.
West Virginia	*No. 3	U. S. Steel Corp., Coal Division
Do.	*No. 6	Do.
Do.	*No. 9	Do.
Do.	No. 10	Do.
Do.	*No. 3	Red Bird Mining Co.
Do.	*Huff Mountain	Redyard Coal Co.
Do.	Olga No. 1	Olga Coal Co.
Do.	Lake Superior No. 3	Lake Superior Coal Co.
Do.	*Hernshaw	Electro-Metallurgical Co.
Wyoming	Brilliant No. 8	The Kemmerer Coal Co.
Do.	*Peacock No. 12	Colony Coal Co.

*Mines appear in both tables 2 and 3.

TABLE 3. - Title II mines at which no imminent dangers (Sec. 203(a)) or violations of Sec. 209 under Title II were observed during an inspection

1954		
State	Mine	Company
Alabama..............	Bessie	U. S. Pipe & Foundry Co.
Do................	Blockton No. 9	Black Diamond Coal Mining Co.
Do.	Marvel No. 1	Cates Coal Co.
Do.	Marvel No. 3	Do.
Do.	New Banner No. 3	Davidson-Pratt Mining Co.
Do.	Dixie	Dixie Fire Brick Co.
Do.	Empire No. 3	DeBardeleben Coal Corp.
Do.	*Hamilton	Tennessee Coal & Iron Division of U. S. Steel Corp.
Do.	Kellerman No. 19	Twin Seam Mining Co.
Do.	*Maxine	Alabama By-Products Corp.
Do.	*Sayre	Republic Steel Corp.
Do.	American No. 5	Stith Coal Co.
Do.	*Docena	Tennessee Coal & Iron Division of U. S. Steel Corp.
Do.	*Dolomite No. 3	Woodward Iron Co.
Do.	*Labuco	Alabama By-Products Corp.
Do.	Moro No. 3	Moro Brothers Coal Co.
Do.	Praco	Alabama By-Products Corp.

*Mines appear in both tables 2 and 3.

APPENDIX H (Con.)

TABLE 3. - Title II mines at which no imminent dangers (Sec. 203(a)) or violations of Sec. 209 under Title II were observed during an inspection (Con.)

1954		
State	Mine	Company
Alabama (Con.)......	*Sayreton No. 1	Republic Steel Corp.
Do...............	*Sayreton No. 2	Do.
Do.	Warrior River No. 4	Brookside-Pratt Mining Co.
Do.	Blue Creek	Black Diamond Coal Mining Co.
Do.	New Banner	Davidson-Pratt Mining Co.
Do.	Black Diamond Nos. 1 and 2	Black Diamond Coal Mining Co.
Do.	Bradford	Alabama By-Products Corp.
Do.	*Concord	Tennessee Coal & Iron Division of U. S. Steel Corp.
Do.	*Edgewater	Do.
Do.	*Gorgas No. 3	Alabama Power Co.
Do.	Thermal No. 1	Alabama By-Products Corp.
Arkansas	No. 1 mine	Dixie Fuel Co.
Do.	Quality No. 2	Quality Excelsior Coal Co.
Do.	Jewell mine	Jewell Mining Co.
Do.	Clarksville	Clarksville Coal Co.
Do.	Peerless No. 3	Peerless Coal Co.
Colorado	Somerset	Minerals Development Corp., Calumet Fuel Division
Do.	*Eagle	Imperial Coal Co.
Do.	Imperial	Do.
Do.	*Morley	Colorado Fuel and Iron Corp.
Do.	Harris	Colorado and Utah Coal Co.
Do.	*Hawk's Nest	Champion Coal Mining Co.
Illinois	Schubert No. 1	Schubert Coal Co.
Do.	Glenridge	Marion County Coal Mining Corp.
Do.	Eddy	Eddy Coal Co.
Do.	North	Breese Coal Co.
Do.	Cantine No. 4	Lumaghi Coal Co.
Do.	Deer Creek	Deer Creek Coal Co.
Do.	Green Diamond	Mid-Continent Coal Corp.
Do.	No. 16	Sahara Coal Company, Inc.
Do.	Golden Rule	Golden Rule Coal Co.
Do.	New Kathleen	Union Colliery Co.
Do.	No. 1	Bluff Coal Co.
Do.	Mary Kay	New West Side Coal Co., Inc.
Do.	Livingston No. 1	Livingston-Mt. Olive Coal Co.
Do.	No. 4	Superior Coal Co.
Do.	Riverton	Farrand Coal Co.
Do.	Little Dog	Little Dog Coal Co.
Do.	Moffat No. 2	Moffat Coal Co.
Do.	No. 1	Joliana Mining Co.
Do.	Crown	Freeman Coal Mining Corp.
Do.	St. Ellen	Perry Coal Co.
Do.	Virden	Virden Mining Co.
Do.	Carmac	Carmac Coal Co.
Do.	Bradbury	Midwest Utilities Coal Corp.

*Mines appear in both tables 2 and 3.

APPENDIX H (Con.)

TABLE 3. - Title II mines at which no imminent dangers (Sec. 203(a)) or violations of Sec. 209 under Title II were observed during an inspection (Con.)

1954		
State	Mine	Company
Illinois (Con.)....	No. 10	Peabody Coal Co.
Do.	No. 8	Do.
Do.	East Breese	Citizens Coal Co.
Do.	New Black Crystal	Black Crystal Coal Co.
Do.	No. 3	No. 3 Coal Corp.
Do.	Bois	Bois Coal Co.
Do.	Kildee No. 3	Pschirrer & Sons Coal Co.
Do.	Lee	Lee Coal Mining Co.
Do.	Belle Valley	Belle Valley Coal Co.
Do.	Murdock mine, Murdock Division	Bell & Zoller Coal Co.
Indiana	No. 1	Three Coal Co.
Do.	White Ash	White Ash Coal Co.
Iowa	New Sterling No. 3	Sunshine Coal Co.
Do.	No. 4	Sunshine Coal Co.
Do.	Shamrock	Shamrock Coal Co.
Do.	Riverside	Riverside Coal Co.
Do.	Old King	Old King Coal Co.
Do.	D. C.	D. C. Coal Co.
Kansas	DeGasperi	DeGasperi Coal Co.
Do.	Quality	Quality Coal Co.
Kentucky	No. 21	The United Electric Coal Co.
Do.	Peckenpaugh	Peckenpaugh Coal Co.
Do.	Meadows	Meadows Coal Co.
Do.	Kirk No. 5	Kirk Coal Mining Co.
Do.	East Diamond	West Kentucky Coal Co.
Do.	Franklin	Franklin Coal Co.
Do.	Williams	Williams Bros. Coal Co.
Do.	No. 1	Wallace Valley Coal Co.
Do.	Pleasant View	West Kentucky Coal Co.
Do.	Coiltown	Coiltown Mining Co.
Do.	Atkinson	West Kentucky Coal Co.
Do.	Lavada	Lavada Coal Co.
Do.	Chesley Franklin	Chesley Franklin Coal Co.
Do.	No. 3	Blanton & Rice Coal Co.
Do.	No. 2	Boldman Fuel Co.
Do.	Hellier No. 2	Cauldill Ward Coal Co.
Do.	New Cinderella	Cinderella Coal Corp.
Do.	C. & C. Alma	Cline & Chambers Coal Co.
Do.	*Hendrix	Consolidation Coal Corp. (Ky.)
Do.	*No. 204	Do.
Do.	*No. 214	Do.
Do.	Stone No. 8	Eastern Coal Corp.
Do.	Stone No. 3	Do.
Do.	Kona No. 2	Elkhorn Coal Corp.
Do.	No. 1	Elkhorn Summitt Coal Co.
Do.	Freeburn	Emporor Coal & Coke Co.
Do.	No. 3	Everidge Coal Co.

*Mines appear in both tables 2 and 3.

APPENDIX H (Con.)

TABLE 3. - Title II mines at which no imminent dangers (Sec. 203(a)) or violations of Sec. 209 under Title II were observed during an inspection (Con.)

1954		
State	Mine	Company
Kentucky (Con.)	No. 1	Feds Creek Coal Co., Inc.
Do.	No. 4	Hellier Coal & Coke Co.
Do.	No. 2	Hill Gail Coal Corp.
Do.	Wisconsin Steel mines	International Harvester Co.
Do.	No. 1	Majestic Collieries
Do.	Poplar Gap No. 1	Do.
Do.	No. 2	M. & B. Collieries, Inc.
Do.	No. 3	Middle Point Coal Co.
Do.	No. 1	Mill Branch Coal Co.
Do.	*Pond Creek	Norfolk & Western Railway Co. (Fuel Dept.)
Do.	*Thacker No. 5	Do.
Do.	*Winifrede No. 2	Do.
Do.	New Alma	New Alma Coal Co.
Do.	No. 3	Peem Coal Co.
Do.	No. 4	Do.
Do.	Alma	Phelps Collieries, Inc.
Do.	*Republic No. 4	Republic Steel Corp.
Do.	*Republic D	Do.
Do.	Russell Fork	Russell Fork Coal Co.
Do.	Laviers No. 2	Southeast Coal Co.
Do.	Big Chief	Do.
Do.	No. 1	Tutor Key Coal Co.
Do.	No. 30	U. S. Steel Co.
Do.	No. 31	Do.
Do.	No. 32	Do.
Do.	No. 4	W. & M. Coal Co.
Do.	No. 3	West Virginia & Kentucky Coal Corp.
Do.	Lampliter	Woodside Mines, Inc.
Do.	Algoma Block No. 5A section	Algoma Block Coal Co.
Do.	Big Jim	Big Jim Coal Co.
Do.	Harlan	Black Star Coal Corp.
Do.	Leatherwood No. 2	Blue Diamond Coal Co.
Do.	No. 5A	Do.
Do.	No. 7	Blue Bird Mining Co.
Do.	No. 9	Carrs Fork Coal Co.
Do.	No. 6	Clear Fork Coal Co.
Do.	Clover Splint	Closplint Coal Co.
Do.	Clover Fork	Clover Fork Coal Co.
Do.	Pacemaker	Congleton Brothers Coal Co.
Do.	Crummies Nos. 1 & 2	Crummies Creek Coal Co.
Do.	Sapphire No. 1	Elkhorn Jellico Coal Co.
Do.	Sapphire No. 2	Do.
Do.	No. W-20	Hagans & Hall Coal Co.
Do.	Brookside	Harlan Collieries Co.
Do.	Hi-Lo No. 2	High Splint Coal Co.
Do.	Sunfire	Kentucky Sun Coal Co.

*Mines appear in both tables 2 and 3.

APPENDIX H (Con.)

TABLE 3. - Title II mines at which no imminent dangers (Sec. 203(a)) or violations of Sec. 209 under Title II were observed during an inspection (Con.)

1954		
State	Mine	Company
Kentucky (Con.).....	No. 9	Knott Coal Corp.
Do.	No. 1	Margin Coal Co.
Do.	Davisburg	Margo Coal Mining Co.
Do.	Mill Ridge	Mill Ridge Coal Co.
Do.	Midland No. 2	Old King Mining Co.
Do.	No. 2	Do.
Do.	Liggett	Parkins Harlan Coal Co.
Do.	Princess No. 1A	Princess Elkhorn Coal Co.
Do.	Princess No. 2	Do.
Do.	No. 12A	Reed and Hayes Coal Co.
Do.	Liberty No. 2	Sammons and Reed Coal Co.
Do.	Smith No. 1	Smith Coal Co.
Do.	No. 2	Do.
Do.	Stoker	Stoker Coal Co.
Do.	*High Splint No. 1 Glenbrook colliery	Stonega Coke and Coal Co.
Maryland	No. 10	Consolidated Fuel Co., Inc.
Missouri	Baiotto	Billy Creek Coal Co.
Do.	Macey	Ashford Coal Co.
Do.	Klondike	Mosby Coal Co., Inc.
Do.	Blacksmith	Blacksmith Coal Co., Inc.
Do.	No. 8	Corrigan Coal Co.
Do.	Bradley	D. L. Bradley Coal Co.
Do.	Ol'Elliott	Moberly Fuel Co., Inc.
Do.	Perry Rice	Perry Rice Coal Co.
Do.	No. 4	Clark Coal Co.
Montana	Brophy	Brophy Coal Co.
Do.	Klein No. 2	Republic Coal Co.
Do.	Roundup No. 3	Roundup Mining Co.
Do.	Keene No. 2	Mountain States Mining Co.
New Mexico	Koehler Nos. 1 and 2	St. Louis, Rocky Mountain & Pacific Co.
Ohio	Dry Fork	Dry Fork Coal Co.
Do.	Piney Fork No. 1	Hanna Coal Co.
Do.	Glen Castle No. 6	Do.
Do.	Norton No. 2	The David Z. Norton Co.
Do.	No. 56	Oskey Coal Co.
Oklahoma	*Carbon No. 5	Lone Star Steel Co.
Do.	*McCurtain	Do.
Do.	Blackstone	Ben Hur Coal Co.
Do.	Starr No. 2	Starr Coal, Inc.
Pennsylvania (anthracite)	*No. 10 slope	Ardoline Coal Co.
Do.	Kidney slope	Bird Mining Co.
Do.	No. 9 slope	Beaver Meadow Mining Co.
Do.	*Kirmar slope	Biscontini & Sons Coal Co.
Do.	*No. 58 slope	Do.

*Mines appear in both tables 2 and 3.

APPENDIX H (Con.)

TABLE 3. - Title II mines at which no imminent dangers (Sec. 203(a)) or violations of Sec. 209 under Title II were observed during an inspection (Con.)

1954		
State	Mine	Company
Pennsylvania (Con.) (anthracite).......	No. 99 slope	Biscontini & Sons Coal Co.
Do.	Boslego slope	Boslego Coal Co.
Do.	No. 3 slope	Brunetti Coal Co.
Do.	No. 91 slope	Steve J. Bilko Coal Co.
Do.	Archbald shaft	The Continental-Archbald Coal Co.
Do.	Packer colliery	Duryea Anthracite Co.
Do.	Hunter Tunnel mine	Drift Contracting Co.
Do.	No. 60 slope	Dimario Coal Co.
Do.	No. 3 slope	Dancott Coal Co.
Do.	Johnson mine	DeAngelis Coal Co.
Do.	No. 1 slope	Joseph P. Dando & Co.
Do.	Buttonwood colliery	Glen Alden Coal Co.
Do.	Empire shaft, Empire-Kidder-colliery	Do.
Do.	Sugar Notch colliery	Do.
Do.	Kidder slope, Empire-Kidder-colliery	Do.
Do.	Huber colliery	Do.
Do.	Nottingham colliery	Do.
Do.	Avondale colliery	Do.
Do.	Wanamie colliery	Do.
Do.	Audenried colliery	Do.
Do.	Loomis colliery	Do.
Do.	South Wilkes-Barre colliery	Do.
Do.	Woodward colliery	Do.
Do.	No. 9 Tunnel mine	Genelow Mining Co.
Do.	No. 30 drift	Gianforcaro Coal Co.
Do.	Powderly mine	Gillen Coal Co.
Do.	No. 14 slope	Gubbiotti Coal Co.
Do.	Gaylord colliery	Gaylord Coal Co.
Do.	Butler slope	Guzior Coal Co.
Do.	No. 5 mine, Loree colliery	The Hudson Coal Co.
Do.	No. 3 mine, Loree colliery	Do.
Do.	Gravity slope	Do.
Do.	Coal Brook colliery	Do.
Do.	Marvine colliery	Do.
Do.	Baltimore colliery	Do.
Do.	No. 4 Lykens slope	Hentz Coal Co.
Do.	Henry E shaft	Harry E Coal Co.
Do.	Heidelberg colliery	Heidelberg Coal Co.
Do.	Indian Head colliery	Indian Head Coal Co.
Do.	Coal Creek slope	Do.
Do.	Stockton colliery, No. 3 slope	Jeddo-Highland Coal Co.

APPENDIX H (Con.)

TABLE 3. - Title II mines at which no imminent dangers (Sec. 203(a)) or violations of Sec. 209 under Title II were observed during an inspection (Con.)

1954		
State	Mine	Company
Pennsylvania (Con.) (anthracite)	Owl Hole mine, Eckley colliery	Jeddo-Highland Coal Co.
Do.	Drifton colliery	Do.
Do.	Jeddo No. 24 slope	Do.
Do.	Highland No. 5 mine	Do.
Do.	Schooley colliery	Knox Coal Co.
Do.	River slope	Do.
Do.	Henry colliery, Henry shaft	Lehigh Valley Coal Co.
Do.	Enterprise slope, Henry colliery	Do.
Do.	Wyoming No. 8 slope, Henry colliery	Do.
Do.	Hazleton shaft	Do.
Do.	Dorrance colliery	Do.
Do.	Humboldt colliery	Lattimer Coal Co.
Do.	Greenwood mine, Tamaqua colliery	Lehigh Navigation Coal Co., Inc.
Do.	No. 18 slope	Labonoski Coal Co.
Do.	Red Ash mine	Larksville Coal Co.
Do.	Seven Foot slope	L. and M. Coal Co.
Do.	Maffei slope	Maffei Coal Co.
Do.	Fuller slope	Maltby Coal Co.
Do.	No. 2 shaft, No. 10 tunnel, Nos. 15 & 16 slopes, Storrs colliery	Moffat Coal Co.
Do.	Erie colliery	Motley Coal Co.
Do.	Connell mine	Mildred Coal Co.
Do.	Nos. 1 & 2 slopes	Michael Mining Co.
Do.	No. 4 slope	Mazzoni Coal Co.
Do.	Molinski colliery	Molinski Coal Co.
Do.	Mountain slope	Mountain Slope Coal Co.
Do.	*No. 1 slope	Newport Excavating Co.
Do.	*No. 2A slope	Do.
Do.	No. 10 slope	Northwest Coal Co.
Do.	*No. 1A slope	Newport Excavating Co.
Do.	No. 52 slope	No. 52 Slope Coal Co.
Do.	No. 9 colliery	No. 9 Coal Co.
Do.	No. 11 slope	No. 11 Coal Co.
Do.	No. 3 tunnel	Penag Coal Co.
Do.	Maple Hill colliery	Phila. & Reading Coal & Iron Co.
Do.	Oak Hill colliery	Do.
Do.	Potts colliery	Do.
Do.	No. 11 slope	Ploskonka Coal Co.
Do.	Taylor shaft	Pyne-Taylor Co., Inc.
Do.	Pyne mine	Do.

*Mines appear in both tables 2 and 3.

APPENDIX H (Con.)

TABLE 3. - Title II mines at which no imminent dangers (Sec. 203(a)) or violations of Sec. 209 under Title II were observed during an inspection (Con.)

1954		
State	Mine	Company
Pennsylvania (Con.) (anthracite)	Primrose slope	Peca Coal Co.
Do.	Breaker slope	Pompey Coal Co.
Do.	Hoyt shaft, Ewen colliery	Pennsylvania Coal Co.
Do.	Bell Mountain slope	Rogers Brothers
Do.	Archbald slope No. 184	Do.
Do.	Renninger colliery	Renninger Coal Co.
Do.	Rushbrook slope	Rushbrook Coal Co.
Do.	No. 2 shaft colliery	Russell Mining Co., Inc.
Do.	Germantown colliery	Raven Run Coal Co.
Do.	No. 16 slope, No. 7 colliery	Susquehanna Collieries Division, The M. A. Hanna Co.
Do.	No. 2 shaft, No. 7 colliery	Do.
Do.	Glen Burn colliery	Do.
Do.	Maysville No. 1 slope, Glen Burn colliery	Do.
Do.	Maysville No. 2 slope, Glen Burn colliery	Do.
Do.	*Glen Lyon colliery	Do.
Do.	Spearhead mine	Spearhead Mining Co.
Do.	Nos. 2, 7, and Rex slopes	Sarf Coal Co.
Do.	Saint Clair colliery	Saint Clair Coal Co.
Do.	Capone colliery	Sam Capone Coal Co.
Do.	Powder Mill Slope mine	Sobleskie Coal Co.
Do.	Penna. No. 1 slope	Snyder Coal Co.
Do.	Sharp Mountain drift	Sharp Mountain Coal Co.
Do.	Sussex slopes	Sussex Coal Co.
Do.	Underwood slope	Village Slope Coal Co.
Do.	Hyde Park mine	West Slope Coal Corp.
Do.	No. 15 slope	West Exeter Coal Mining Co.
Pennsylvania (bituminous)	Avenue No. 2	Allegheny Coal & Coke Co.
Do.	Banning No. 1	Republic Steel Corp.
Do.	Black Hollow	Mateer Coal Co.
Do.	Bowman No. 2	Bowman Coal Co.
Do.	*Bridgeport	U. S. Steel Corp.
Do.	*Collier	Do.
Do.	Colonial Plant	Do.
Do.	Coyer No. 3	I. E. & Walter Coyer Coal
Do.	Decker No. 3	Powell Coal Co.
Do.	Dunkard No. 2	Island Coal Co.
Do.	Evans No. 3	Evans Coal Co.
Do.	Fleck No. 3	Fleck Coal Co.
Do.	Frogtown	Allaman Mining Co.
Do.	*Harwick	Duquesne Light Co.

*Mines appear in both tables 2 and 3.

APPENDIX H (Con.)

TABLE 3. - Title II mines at which no imminent dangers (Sec. 203(a)) or violations of Sec. 209 under Title II were observed during an inspection (Con.)

1954		
State	Mine	Company
Pennsylvania (Con.)		
(bituminous).......	*Indianola	Republic Steel Corp.
Do.	*Isabella	Weirton Coal Co.
Do.	*Karen	U. S. Steel Corp.
Do.	Leckrone No. 2	Leckrone Coal & Coke Co.
Do.	Leisenring No. 1	U. S. Steel Corp.
Do.	*Leisenring No. 2	Do.
Do.	*Leisenring No. 3	Do.
Do.	Magee	Westmoreland Coal Co.
Do.	*Maxwell	U. S. Steel Corp.
Do.	Melcroft	Eastern Gas & Fuel Assoc.
Do.	Moffitt	Molnar Bros. Coal Co.
Do.	Montour No. 4	Pittsburgh Coal Co.
Do.	Montour No. 8	Sal-Ray Coal Co., Inc.
Do.	Myers No. 3	Geo. K. Brennen
Do.	National No. 3	U. S. Steel Corp.
Do.	No. 1	North Sewickly Coal Co.
Do.	Old Eagle	Rathgeb & Gorr Coal Co.
Do.	Park-Armstrong	Leechburg Mining Co.
Do.	Pennsy	Bowie Coal Co.
Do.	*Poland No. 1	Molnar Bros. Coal Co.
Do.	Riddle	Sarver Coal Co.
Do.	Ronco	U. S. Steel Corp.
Do.	Rovella	Kerry Coal Co.
Do.	*Russellton	Republic Steel Corp.
Do.	Seger No. 1	Atlantic Crushed Coke Co.
Do.	No. 6	Sekora's Coal
Do.	*Springdale	Allegheny Pittsburgh Coal Co.
Do.	Turkey Run	C. H. & R. Coal Co., Inc.
Do.	Wildwood	Butler Consolidated Coal Co.
Do.	York Run No. 3	Williams Coal Co.
Do.	No. 2 mine	Acosta-Gray Co.
Do.	No. 8 mine	"B" Quality Coal Co.
Do.	Eureka No. 35 Upper mine	Berwind-White Coal Mining Co.
Do.	No. 72 mine	Bethlehem Mines Corp.
Do.	No. 73 mine	Do.
Do.	No. 74 mine	Do.
Do.	No. 2 mine	Bird Coal Co.
Do.	Cambria No. 11 mine	Cambria Fuel Co.
Do.	Cambria Mills No. 2 mine	Cambria Mills Coal Co.
Do.	Sal No. 1 mine	Coal Mining Company of Graceton, Inc.
Do.	Sonman Slope "E" mine	Eastern Gas and Fuel Associates, Coal Division
Do.	Huskin No. 6 mine	Gahagen Coal Co.
Do.	Haws Shaft mine	Haws Refractories Co.
Do.	Hoover No. 1 mine	I. H. Hoover & Son
Do.	Lilly No. 3 mine	C. A. Hughes & Co.

*Mines appear in both tables 2 and 3.

APPENDIX H (Con.)

TABLE 3. - Title II mines at which no imminent dangers (Sec. 203(a)) or violations of Sec. 209 under Title II were observed during an inspection (Con.)

1954		
State	Mine	Company
Pennsylvania (Con.)		
(bituminous).......	Cambria Smokeless No. 1 mine	Imperial Coal Corp.
Do.	Cardiff No. 1 mine	Do.
Do.	Imperial Keystone mine	Do.
Do.	Portage No. 4 mine	Johnstown Coal & Coke Co.
Do.	Lingle No. 7 mine	Lingle Coal Co.
Do.	Loyal Hanna No. 6 mine	Loyal Hanna Coal & Coke Co.
Do.	McClure No. 2 mine	McClure Coal Co.
Do.	Maxton Slope No. 1 mine	Morrisdale Coal Mining Co.
Do.	No. 1 mine	Morrison Coal Co.
Do.	Mt. Carmel No. 2 mine	Moshannon Falls Mining Co.
Do.	Kramer mine	Northwestern Mining & Exchange Co.
Do.	Ponfeigh Pine Hill mine	Pine Hill Smokeless Coal Co.
Do.	Sonman No. 2 mine	W. H. Piper and Company, Inc.
Do.	Reitz No. 3 Lower mine	Reitz Coal Co.
Do.	Reitz No. 4 mine	Do.
Do.	Ernest No. 1 mine	Rochester & Pittsburgh Coal Co.
Do.	Kent No. 2A mine	Do.
Do.	Kent No. 5 mine	Do.
Do.	Troxell No. 2 mine	Scott Bros. Coal Co.
Do.	Scurfield No. 2 mine	Scurfield Coal Co.
Do.	Sterling No. 6 mine	Sterling Coal Co.
Do.	Harrison No. 2 mine	The Saxman Coal and Coke Co.
Do.	Tyler No. 14 mine	Underhill Coal Mining Co.
Do.	Orchard No. 5 mine	Woolridge Coal Co.
Do.	Pheasant Hollow mine	Worthville Coal Co.
Do.	Lincoln mine	Joseph E. Yobbagy
Tennessee...........	No. 1	Rich Mountain Coal Co.
Do.	Meadow Creek	Clinchfield Coal Corp.
Do.	No. 1	New River Fuel Co.
Do.	Red Ash No. 2	High Point Coal Co.
Do.	No. 1	Mountain Top Coal Co.
Do.	Moore	Pocahontas Fuel Co.
Do.	Coal Valley	Tennessee Consolidated Coal Co.
Do.	ABC mine	A B C Coal Co.
Do.	Southern collieries mine	Southern Collieries, Inc.
Do.	No. 7	Fentress Coal and Coke Co.
Do.	No. 1	Hood and Mullinix Coal Co.
Utah	King	United States Fuel Co.
Do.	Western	Western Coal Mining Co.
Do.	Rains No. 3	Hi-Heat Coal Co.
Do.	Columbia	Columbia-Geneva Steel Division United States Steel Corp.
Do.	*Sunnyside No. 2	Kaiser Steel Corp.
Do.	Wattis Nos. 1 & 2	Lion Coal Corp.
Do.	Castle Gate No. 2	Independent Coal & Coke Co.
Do.	Spring Canyon No. 4	Spring Canyon Coal Co.

*Mines appear in both tables 2 and 3.

APPENDIX H (Con.)

TABLE 3. - Title II mines at which no imminent dangers (Sec. 203(a)) or violations of Sec. 209 under Title II were observed during an inspection (Con.)

1954		
State	Mine	Company
Utah (Con.).........	Geneva	Columbia-Geneva Steel Division, United States Steel Corp.
Do.	*Book Cliffs	Book Cliffs Coal Co.
Do.	*Sunnyside No. 3	Kaiser Steel Corp.
Do.	Clear Creek	Independent Coal & Coke Co.
Do.	Browning	Arthur J. Petty
Virginia	Calvin	Blackwood Fuel Co.
Do.	No. 2	Cassell Coal Co.
Do.	No. 4	Christie Coal & Coke Co.
Do.	No. 9	Clinchfield Coal Corp.
Do.	*Moss No. 1	Do.
Do.	*Moss No. 3	Do.
Do.	Moss No. 4	Do.
Do.	Meade No. 2	Do.
Do.	No. 2	Garden Smokeless Coal Co.
Do.	No. 3	Holly Creek Coal Co.
Do.	No. 3	Lambert Coal Co.
Do.	No. 1	Lyttle Coal Co.
Do.	North Side	North Side Coal Co.
Do.	No. 1	Page Pocahontas Coal Corp.
Do.	Meade	Pressley Coal Co.
Do.	Seaboard No. 1	Rebecca Coal Co.
Do.	Kennedy	Red Jacket Coal Corp.
Do.	Keen Mountain	Do.
Do.	Tacoma	Ruth Elkhorn Coals, Inc.
Do.	Splash Dam	Splash Dam Coal Corp.
Do.	*Crossbrook	Stonega Coke & Coal Co.
Do.	*Moss No. 2	Clinchfield Coal Corp.
Do.	Derby	Stonega Coke and Coal Co.
Do.	Roda No. 3	Do.
Do.	Roda No. 5	Do.
Do.	Buccaneer No. 3	Sycamore Coal Corp.
Do.	Virginia-Lee	Virginia Lee Co., Inc.
Do.	No. 2	Willie Bentley Coal Co.
Do.	No. 4	Wise Coal & Coke Co.
Washington	Jones	B. & R. Coal Co.
West Virginia	No. 1	Pine Swamp Mining Co.
Do.	Bergoo No. 4 4B Opening	Pardee and Curtin Lumber Co.
Do.	Haller	Haller Coal Co.
Do.	No. 4	Pardee and Curtin Lumber Co.
Do.	Kingmont	The Virginia and Pittsburgh Coal & Coke Co.
Do.	Borgman No. 5	Borgman Coal Co.
Do.	Borgman No. 10	Do.
Do.	Glen Cambria No. 1	Mountain Fuel Co.
Do.	Mason-Dixon No. 1	L. and W. Coal Co.
Do.	Oak Ridge	Kemp Coal Co.

*Mines appear in both tables 2 and 3.

APPENDIX H (Con.)

TABLE 3. - Title II mines at which no imminent dangers (Sec. 203(a)) or violations of Sec. 209 under Title II were observed during an inspection (Con.)

1954		
State	Mine	Company
West Virginia (Con.)	Lockview No. 2	Lockview Coal Co.
Do.	Wendel, Nos. 1 and 2	Wendel Coal Co.
Do.	East Run air shaft	Joanne Coal Co.
Do.	No. 4	Johnson Coal Co.
Do.	Johnstown No. 1	Harris Coal Co.
Do.	No. 3	Compass Coal Co.
Do.	Canyon	Tasa Coal Co.
Do.	No. 2	G. and L. Coal Co.
Do.	Berryburg No. 1	Smith Coal Co.
Do.	Junior No. 2	Junior Coal Co.
Do.	Ream No. 6B	Kray Coal Co., Inc.
Do.	No. 2	Compass Coal Co.
Do.	Nixon mine, Nos. 4 and 5 openings	Nixon Coal Co.
Do.	No. 4	Bakers Ridge Coal Co.
Do.	Ream No. 1	Kray Coal Co.
Do.	Tunnelton	Tunnelton Cooperative Coal Co.
Do.	Lynn mine	Lake Lynn Fuel Co.
Do.	Acme	Acme Coal Co.
Do.	Bakers Ridge No. 3	Bakers Ridge Coal Co.
Do.	Ream No. 2	Kray Coal Co.
Do.	Beech Bottom	Windsor Power House Coal Co.
Do.	Donegan 3-C	Donegan Coal & Coke
Do.	Peach Cr. Chilton	Jewell Ridge Coal Co.
Do.	No. 1	Buffalo Chilton Coal Co.
Do.	No. 2	Shamblin Coal Co.
Do.	No. 10	Slab Fork Coal Co.
Do.	Lieving	Lieving Coal Co.
Do.	Page No. 8	Eastern Gas & Fuel Associates
Do.	No. 3	Guyan Eagle Coal Co.
Do.	No. 8	Lorado Coal Mining Co.
Do.	Pinnacle No. 6	Am. Coal Co. of Allegany County
Do.	Herndon	Lamar Colliery Co.
Do.	Snap Creek No. 2	Snap Creek Coal Co.
Do.	No. 1	Chilton Hernshaw Coal Co.
Do.	No. 6A	Imperial Colliery Co.
Do.	No. 1-C	Amherst Coal Co.
Do.	*No. 6	U. S. Steel Corp.
Do.	Brule 5, 3 & 4	Brule Smokeless Coal Co.
Do.	No. 3	Arlington Poca. Coal Co.
Do.	Ashland No. 6	Ashland Mining Corp.
Do.	No. 9	Do.
Do.	McDowell No. 6	Do.
Do.	No. 9	Arlington Pocahontas
Do.	No. 6	Arlington Pocahontas Coal Co.
Do.	Kopperston No. 2	Eastern Gas & Fuel Associates
Do.	*No. 3	U. S. Steel Corp., Coal Division
Do.	Lady Dunn 100A	Cannelton Coal & Coke Co.

*Mines appear in both tables 2 and 3.

APPENDIX H (Con.)

TABLE 3. - Title II mines at which no imminent dangers (Sec. 203(a)) or violations of Sec. 209 under Title II were observed during an inspection (Con.)

1954		
State	Mine	Company
West Virginia (Con.)	Page	Page Coal & Coke
Do.	Angle	Pocahontas Fuel Co.
Do.	Wyco	Clinchfield Coal Corp.
Do.	Coaldale	Pocahontas Fuel Co., Inc.
Do.	Medo Fuel	Medo Fuel Co.
Do.	No. 14-No. 3 Seam	U. S. Steel Corp., Coal Division
Do.	No. 5	Orlandi Coal Co.
Do.	Page No. 7	Eastern Gas & Fuel Associates
Do.	No. 6 East	U. S. Steel Corp., Coal Division
Do.	*Huff Mountain	Redyard Coal Co.
Do.	Quinwood No. 3	Imperial Smokeless Coal Co.
Do.	*No. 9	U. S. Steel Corp., Coal Division
Do.	No. 5 Block	Truax-Traer Coal Co.
Do.	Sewell Chief	Woolridge Coal Mining Co.
Do.	No. 2	Swiss Coal Co.
Do.	No. 2	U. S. Steel Corp., Coal Division
Do.	Ansted	Gauley Mountain Coal Co.
Do.	Crane Cr. Nos. 1 & 9	American Coal Co.
Do.	No. 4	Ridgeview Coal Co.
Do.	No. 11	Page Coal & Coke Co.
Do.	No. 17 Bottom	Red Jacket Coal Corp.
Do.	Coal Mountain No. 9	Do.
Do.	*Hernshaw	Electro-Metallurgical Co.
Do.	Emily	Warner Collieries
Do.	Arlington No. 1	Arlington Pocahontas
Do.	No. 3	Craigsville Coal Co.
Do.	*No. 3	Red Bird Mining Co.
Do.	Van No. 1	Youghiogheny & Ohio Coal Co.
Do.	McGregor No. 6	Amherst Coal Co.
Do.	No. 1	Otter Creek Coal Co.
Do.	No. 5	Guyan Eagle Coal Co.
Do.	Piedmont	American Coal Co.
Do.	Slab Fork No. 1	Slab Fork Coal Co.
Do.	No. 22	Island Creek Coal Co.
Do.	No. 26	Do.
Do.	Nellis No. 5	Armco Steel Co.
Do.	KC No. 5	Valley Camp Coal Co.
Do.	No. 7	Riverton Coal Co.
Do.	LeMoyne No. 2	Chemical Coal Co.
Do.	Cornelia	Peters Creek Coal Co.
Do.	No. 1 Punch	Red Parrot Coal Co.
Do.	Carbon No. 12	Carbon Fuel Co.
Do.	Crane Cr. No. 11	Am. Coal Company of Allegany County
Do.	Pinnacle N & S	Do.
Do.	Montcoal No. 1	Armco Steel Corp.
Do.	No. 3	Wyborn Coal Co.
Do.	Royalty No. 1	Royalty Smokeless Coal Co.
Do.	Royalty 2A	Do.
Do.	No. 2	Electro-Metallurgical Co.
Do.	East Gulf 2-A	C. H. Mead Coal Co.
Do.	No. 1	Gray Eagle Coal Co.
Wyoming	*Peacock No. 12	Colony Coal Co.
Do.	D. O. Clark	The Union Pacific Coal Co.

*Mines appear in both tables 2 and 3.

APPENDIX I

TABLE 1. - Distribution of Coal-Mine Inspectors and Electrical Inspectors
December 31, 1954

Office	Coal-mine inspectors						Coal-mine electrical inspectors		
	GS-9	GS-11	GS-12	GS-13	GS-14	Total	GS-9	GS-11	Total
Anchorage			1			1			
Seattle			2			2			
Denver	2	5	4		1	12			
Salt Lake City	1	1	2	1		5			
Phoenix		1				1			
Duluth		1				1			
McAlester		3	1	1		5		1	1
Birmingham	3	6	3		1	13			
Jellico	1	6	2	1		10	1		1
Pittsburgh	4	8	9		1	22	1	1	2
Johnstown	7	5	8	1		21	1		1
St. Clairsville	4	5	3	1		13			
Morgantown	2	9	5	1		17	1		1
Mt. Hope	6	17	12		1	36			
Norton	8	12	7	1		28		1	1
Barbourville	6	8	4	1		19		1	1
Vincennes	2	9	9	1	1	22		1	1
Wilkes-Barre	3	13	10		1	27			
General				5		5			
Total	49	109	82	14	6	1/260	4	5	9
Vacancies						13			1
Allotted						273			10

1/ Includes:
6 district supervisors (excluding Districts F and G).
8 subdistrict supervisors (excluding Seattle, Phoenix, and Albany, N. Y.).
2 safety representatives (Liaison Officers - Washington).
2 technical assistants (Washington).
1 mines safety representative (Holmes Safety Association).

APPENDIX I (Con.)

TABLE 2. - Distribution of engineers
December 31, 1954

Office	GS-9	GS-11	GS-12	GS-13	GS-14	GS-15	Total
Anchorage							
Seattle		1					1
Denver			1	1			2
Salt Lake City			1	1			2
Phoenix							
Duluth		1					1
McAlester							
Birmingham			1				1
Jellico			1				1
Pittsburgh		1	5	2			8
Johnstown			1				1
St. Clairsville		1					1
Morgantown			1				1
Mt. Hope	2	1	3				6
Norton	1		1				2
Barbourville							
Vincennes	1	1	1	1			4
Wilkes-Barre			2				2
General				2	2	1	5
Total	4	6	18	7	2	1	38
Vacancies							7
Allotted							45
Grand total							45

APPENDIX J

Miscellaneous special assignments

Type of job	Anchorage	Seattle	Denver	Salt Lake City	Phoenix	Duluth	McAlester	Birmingham	Jellico	Pittsburgh	Johnstown	St. Clairsville	Morgantown	Mt. Hope	Norton	Barbourville	Vincennes	Wilkes-Barre	Total
Investigating auxiliary blower fans	0	4	13	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	18
Study of mining systems	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Study of cleaning plants (dust)	0	7	0	0	0	0	0	0	0	0	6	7	0	0	0	3	5	0	28
Investigating mine fires, explosions	0	3	3	2	0	0	0	0	1	0	0	5	4	7	0	5	0	0	30
Investigating nonfatal accidents	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Participating in legal litigations	0	0	3	0	0	0	0	2	3	0	0	0	0	0	1	1	0	0	10
Investigating non-coal-mine accidents	0	0	1	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Study of electrical circuits and equipment	0	0	16	1	0	0	2	10	0	2	0	1	0	1	0	0	2	0	35
Tests of diesel locomotives (noncoal)	0	0	3	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5
Haulage study	0	0	2	2	0	0	0	0	0	4	0	0	0	0	0	1	0	0	9
Escorting visitors to mines and plants	0	0	4	2	0	0	0	0	0	9	3	0	0	0	0	0	0	0	18
Participated in civil defense maneuvers	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
Ventilation study	0	0	2	9	0	0	2	0	0	2	0	0	0	0	0	0	3	0	18
Investigating surface fires and explosions	0	0	1	1	0	0	0	0	0	0	0	3	0	1	0	0	0	0	6
Study of dust-allaying equipment	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	3
Safety inspection noncoal mines	0	0	0	2	8	0	2	0	0	0	0	0	0	0	0	0	0	0	12
Work on outcrop and abandoned mine fires	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	1	4
Assisting in the recovery of sealed fire area	0	0	4	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	7
Attending safety meetings	0	0	20	10	0	3	21	0	9	5	4	0	33	0	0	0	54	0	159
Assisting State departments	0	0	4	0	0	1	4	1	2	0	0	0	0	0	0	0	1	0	13
Officiating at first-aid and mine rescue contests	0	1	0	1	0	0	0	0	2	0	0	0	5	0	0	0	2	0	11
Explosives study	0	0	0	0	0	0	3	0	0	4	0	1	0	0	0	0	3	0	11
Attending job-training course	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Conferences with other Federal agencies	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
Roof-control study	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2
Float-dust studies	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Conducting electrical safety course	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Assisting in mine-gasification project	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Congressional hearings on underground gas storage	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Revisions of face equipment permissibility schedule	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	3
Assisting in safety motion pictures	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
Federal Coal-Mine Safety Board of Review hearings	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Miscellaneous	0	0	10	4	1	6	9	1	1	10	0	3	1	3	1	2	6	0	58

APPENDIX K

TABLE 1. - Number of injuries and rates per million man-hours exposure (portal-to-portal)

Period[1]	Fatal	Nonfatal	Man-hours	Rate		Change, percent			
				Fatal	Nonfatal	Fatal	Rate	Nonfatal	Rate
BITUMINOUS									
1932-41....	10,036	447,199	6,794,840,163	1.48	65.81				
1942-51....	8,889	416,646	7,496,573,667	1.18	55.58	-11	-20	-7	-16
1952-54[2]...	1,178	60,999	1,303,474,065	.90	46.80				
ANTHRACITE									
1932-41....	2,295	151,299	1,428,093,979	1.61	105.94				
1942-51....	1,537	110,234	1,374,622,564	1.11	80.19	-33	-31	-27	-26
1952-54[2]...	225	14,355	216,354,245	1.04	66.35				

1/ Calendar year.
2/ Final figures for 1952 included; 1953-54 are preliminary.

APPENDIX K (Con.)

TABLE 2. - Number of fatal and nonfatal injuries and injuries per million man-hours exposure, portal-to-portal, in coal mines of the United States

Calendar year	Fatal injuries						Nonfatal injuries					
	Bituminous		Anthracite		Total		Bituminous		Anthracite		Total	
	Number	Rate	Number	Rate	Number	Rate	Number	Rate	Number	Rate	Number	Rate
1932....	958	1.77	249	1.59	1,207	1.73	39,352	72.58	16,931	107.88	56,283	80.50
1933....	833	1.31	231	1.49	1,064	1.34	43,946	68.87	15,183	98.13	59,129	74.58
1934....	958	1.41	268	1.50	1,226	1.43	46,982	69.39	18,577	104.15	65,559	76.63
1935....	968	1.46	274	1.78	1,242	1.52	47,529	71.47	15,897	103.16	63,426	77.43
1936....	1,098	1.43	244	1.56	1,342	1.45	50,514	65.62	17,026	108.80	67,540	72.91
1937....	1,198	1.54	215	1.58	1,413	1.55	52,847	68.05	13,412	98.72	66,259	72.62
1938....	880	1.52	225	1.94	1,105	1.59	36,794	63.47	12,842	110.85	49,636	71.36
1939....	867	1.36	211	1.71	1,078	1.42	38,544	60.52	13,229	107.37	51,773	68.12
1940....	1,204	1.68	184	1.50	1,388	1.65	43,994	61.28	13,782	112.55	57,776	68.75
1941....	1,072	1.35	194	1.49	1,266	1.37	46,637	58.93	14,420	110.83	61,057	66.26
1942....	1,245	1.41	226	1.64	1,471	1.44	53,193	60.21	13,581	98.73	66,774	65.40
1943....	1,225	1.39	226	1.50	1,451	1.40	51,067	57.79	13,527	89.68	64,594	62.44
1944....	1,124	1.23	174	1.06	1,298	1.20	51,253	56.02	12,438	76.05	63,691	59.06
1945....	925	1.13	143	1.01	1,068	1.11	46,194	56.52	10,923	77.32	57,117	59.58
1946....	795	1.09	173	1.14	968	1.10	42,817	58.81	12,533	82.65	55,350	62.93
1947....	985	1.23	173	1.18	1,158	1.22	46,025	57.32	11,635	79.41	57,660	60.72
1948....	862	1.15	137	.91	999	1.11	42,078	56.28	11,394	75.69	53,472	59.53
1949....	494	.93	91	.83	585	.91	27,548	51.67	7,857	71.88	35,405	55.11
1950....	550	.92	93	.80	643	.90	28,390	47.73	8,874	76.14	37,264	52.38
1951....	684	1.16	101	.95	785	1.13	28,081	47.56	7,472	69.94	35,553	50.99
1952....	449	.90	99	1.03	548	.92	23,719	47.64	6,355	66.35	30,074	50.66
1953 1/..	396	.84	64	.91	460	.84	21,820	46.04	4,455	63.09	26,275	48.25
1954 1/..	333	1.00	62	1.24	395	1.04	15,460	46.62	3,545	70.96	19,005	49.81

1/ Preliminary data subject to revision.

APPENDIX K (Con.)

TABLE 3. - Major coal-mine disasters in the United States and number of persons killed

Calendar year	Number of major disasters	Number of persons killed
1932	6	145
1933	1	7
1934	2	22
1935	4	35
1936	5	37
1937	6	101
1938	6	84
1939	1	28
1940	6	276
1941	8	73
1942	7	132
1943	8	174
1944	4	94
1945	5	68
1946	2	27
1947	6	179
1948	6	49
1949	0	0
1950	0	0
1951	5	157
1952	2	11
1953	1	5
1954	1	16

APPENDIX K (Con.)

TABLE 4. - Underground fatality experience in the coal industry, Title I and Title II mines

	1954	1953	1952	1951
Bituminous:				
Title I mines:				
Fatalities	58	57	60	69
Percent	19.9	16.3	15.4	11.2
Rate1/	3.55	2.40	2.32	2.41
Title II mines:				
Fatalities	233	292	329	549
Percent	80.1	83.7	84.6	88.8
Rate1/	.98	.85	.87	1.32
Total fatalities	291	349	389	618
Rate1/	1.15	.95	.97	1.39
Anthracite:				
Title I mines:				
Fatalities	13	11	16	8
Percent	25.5	18.3	18.8	9.0
Rate1/	26.53	16.38	17.15	8.05
Title II mines:				
Fatalities	38	49	69	81
Percent	74.5	81.7	81.2	91.0
Rate1/	1.14	1.07	1.08	1.20
Total Fatalities	51	60	85	89
Rate1/	1.51	1.29	1.32	1.30
All coal:				
Title I mines:				
Fatalities	71	68	76	77
Percent	20.8	16.6	16.0	10.9
Rate1/	4.22	2.80	2.84	2.61
Title II mines:				
Fatalities	271	341	398	630
Percent	79.2	83.4	84.0	89.1
Rate1/	1.01	.87	.90	1.31
Total fatalities	342	409	474	707
Rate1/	1.19	.98	1.01	1.38

1/ Per million man-hours.
Note: All figures for 1953 and 1954 subject to slight revision.

APPENDIX L

Number of coal mines in the United States in which major improvements were made, 1954 and 1941-54

	Alabama	Alaska	Arizona	Arkansas	California	Colorado	Georgia	Idaho	Illinois	Indiana	Iowa	Kansas	Kentucky	Maryland	Michigan	Missouri	Montana	New Mexico	North Carolina	North Dakota	Ohio	Oklahoma	Oregon	Pennsylvania (anthracite)	Pennsylvania (bituminous)	Tennessee	Texas	Utah	Virginia	Washington	West Virginia	Wyoming	Total 1954	Total 1941-1954
1. Systematic roof-support adopted ..	1	1	0	4	-	2	0	0	11	1	0	0	43	0	-	7	1	1	-	0	33	0	0	2	25	21	-	4	26	0	29	0	212	2,475
2. Roof-support plan enforced	4	1	1	9	-	5	0	0	42	11	0	3	165	1	-	15	7	14	-	0	118	3	0	209	74	72	-	7	76	0	142	0	979	(1)
3. Use of black blasting powder discontinued	12	0	0	0	-	0	0	0	11	4	1	0	14	1	-	1	3	4	-	1	8	1	0	0	17	58	-	0	10	0	0	0	146	1,624
4. New main fan installed	14	0	0	1	-	5	0	0	7	2	0	0	69	1	-	2	0	3	-	0	12	2	0	5	36	34	-	1	23	1	39	0	257	2,919
5. Ventilation generally improved ...	6	3	1	3	-	7	0	0	60	15	2	1	146	8	-	9	2	4	-	2	70	1	0	63	72	46	-	15	56	1	83	5	681	(1)
6. Auxiliary blower fans removed	0	0	0	0	-	0	0	0	0	2	0	0	7	0	-	1	2	0	-	0	3	0	0	0	13	0	-	2	6	0	0	2	38	586
7. Preshift examinations for gas begun	6	1	0	2	-	2	0	0	8	6	0	0	48	10	-	8	6	4	-	0	13	0	0	8	43	8	-	2	21	0	47	1	244	3,146
8. Onshift examinations for gas begun	2	1	0	3	-	4	0	0	19	4	0	0	41	9	-	12	5	5	-	0	19	0	0	8	20	14	-	3	23	0	47	2	241	2,236
9. Use of water to allay dust begun..	1	1	0	0	-	0	0	0	1	0	0	0	3	0	-	0	0	0	-	0	0	0	0	0	3	0	-	8	3	0	5	0	25	1,028
10. Rock dust used for first time	4	1	0	0	-	1	0	0	2	0	0	0	23	0	-	0	0	0	-	0	13	0	0	0	7	6	-	2	60	0	10	0	129	1,868
11. General improvement in rock dusting	1	2	0	4	-	17	0	0	88	16	0	1	170	2	-	0	1	7	-	0	41	2	0	0	34	8	-	13	49	0	99	4	559	(1)
12. General improvement in haulage ...	1	2	0	1	-	2	0	0	8	5	0	1	51	0	-	7	0	0	-	0	53	4	0	24	37	1	-	1	11	0	170	2	381	(1)
13. Installation of protective electric devices	13	2	1	9	-	16	0	0	33	25	8	3	138	2	-	16	3	2	-	8	140	3	0	36	52	3	-	20	23	1	283	5	845	(1)
14. Second opening provided	4	0	0	0	-	2	0	0	3	3	0	0	11	1	-	0	0	0	-	0	3	0	1	7	9	10	-	2	2	0	21	2	81	963
15. Smoking underground discontinued..	5	0	0	2	-	0	0	0	11	11	0	0	10	1	-	0	3	0	-	0	10	0	0	2	18	7	-	0	8	0	18	0	106	1,679
16. Use of open lights discontinued ..	11	0	1	2	-	0	0	0	8	1	0	0	13	2	-	0	0	4	-	0	3	0	0	2	16	4	-	1	15	0	17	2	102	1,482

1/ Grand totals not given for these items because further improvements may have been made in some mines previously reported as showing improvements of the same type.

[illegible]

Bureau of Mines
Information Circular 7735

METHODS AND OPERATIONS AT THE KAISER STEEL CORP. EAGLE MOUNTAIN IRON MINE RIVERSIDE COUNTY, CALIF.

BY R. R. TRENGOVE

United States Department of the Interior — February 1956

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UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
Thos. H. Miller, Acting Director

February 1956

METHODS AND OPERATIONS AT THE KAISER STEEL CORP. EAGLE MOUNTAIN IRON MINE RIVERSIDE COUNTY, CALIF.

By

R. R. Trengove [1]

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TABLES

1/ Mining engineer, Bureau of Mines, Reno, Nev.

Information Circular 7735

ILLUSTRATIONS

INTRODUCTION

This paper is one of a series published by the Bureau of Mines on mining methods and operation practices. It describes the open-pit mining method and operations of the Kaiser Steel Corp. Eagle Mountain iron-ore mine, which is in the extreme southeastern part of California 175 miles east of Los Angeles in Riverside County. Nearest town to the mine is Indio, which is 60 miles away by an excellent highway (fig. 1). Elevations at the deposit vary from 1,400 to 3,000 feet. Figure 2 is a plan map of the Eagle Mountain iron mine.

Kaiser Steel Corp. built a model camp at the mine, with all modern conveniences (fig. 3). The camp, comprising 145 homes, dormitories, mess hall, commissary, post office, and recreational facilities for 600 people, is at 1,390-foot elevation. The area has winter-resort weather between October and May, with occasional drops of temperature to 25° at night. From June to September temperatures sometimes rise to 120° during the day. Rainfall is scant, approximately 2 inches a year, the majority of which comes as cloudbursts during the summer months.

Iron outcrops run roughly east-west along foothills in a spur of the Eagle Mountains. This is the extreme eastern end of the iron formation that extends about 7 miles westward (fig. 4).

The property produces all the blast-furnace ore requirements for the company Fontana, Calif., steel plant. With three blast furnaces in production, about 2-1/4 million tons of iron ore will be required yearly.

ACKNOWLEDGMENTS

Acknowledgment is made to the Kaiser Steel Corp. for its assistance in preparing and publishing this information circular. Special acknowledgment is due to R. G. Heers, manager, Mining and Raw Materials; Kenneth B. Powell, superintendent, and B. A. Binckley, assistant superintendent, both of Raw Materials; M. J. Naughten, safety director; and John Bennett, safety supervisor; J. G. Hansen, mine superintendent; and W. A. Horton, pit foreman. Certain information in this report was obtained from published articles by Kenneth B. Powell[2/] and George W. Huseman,[3/] technical employees of the Kaiser Steel Corp.

HISTORY

The importance of the Eagle Mountain district as a potential source of iron ore on the Pacific coast was recognized early in the century by E. H. Harriman of the Southern Pacific Railroad. Over 100 claims were acquired and patented in 1908; but until the late 1930's, this area had no usable roads, water, or power. During this period far western iron-ore deposits held little commercial interest.

2/ Powell, K. B., Eagle Mountain Helps Kaiser Meet Growing Steel Need: AIME Min. Eng., May 1953, pp. 478-482.

3/ Huseman, G. W., Kaiser Stepping Up Production at Eagle Mountain Iron Mine: Eng. and Min. Jour., vol. 154, No. 5, May 1953, pp. 80-86.

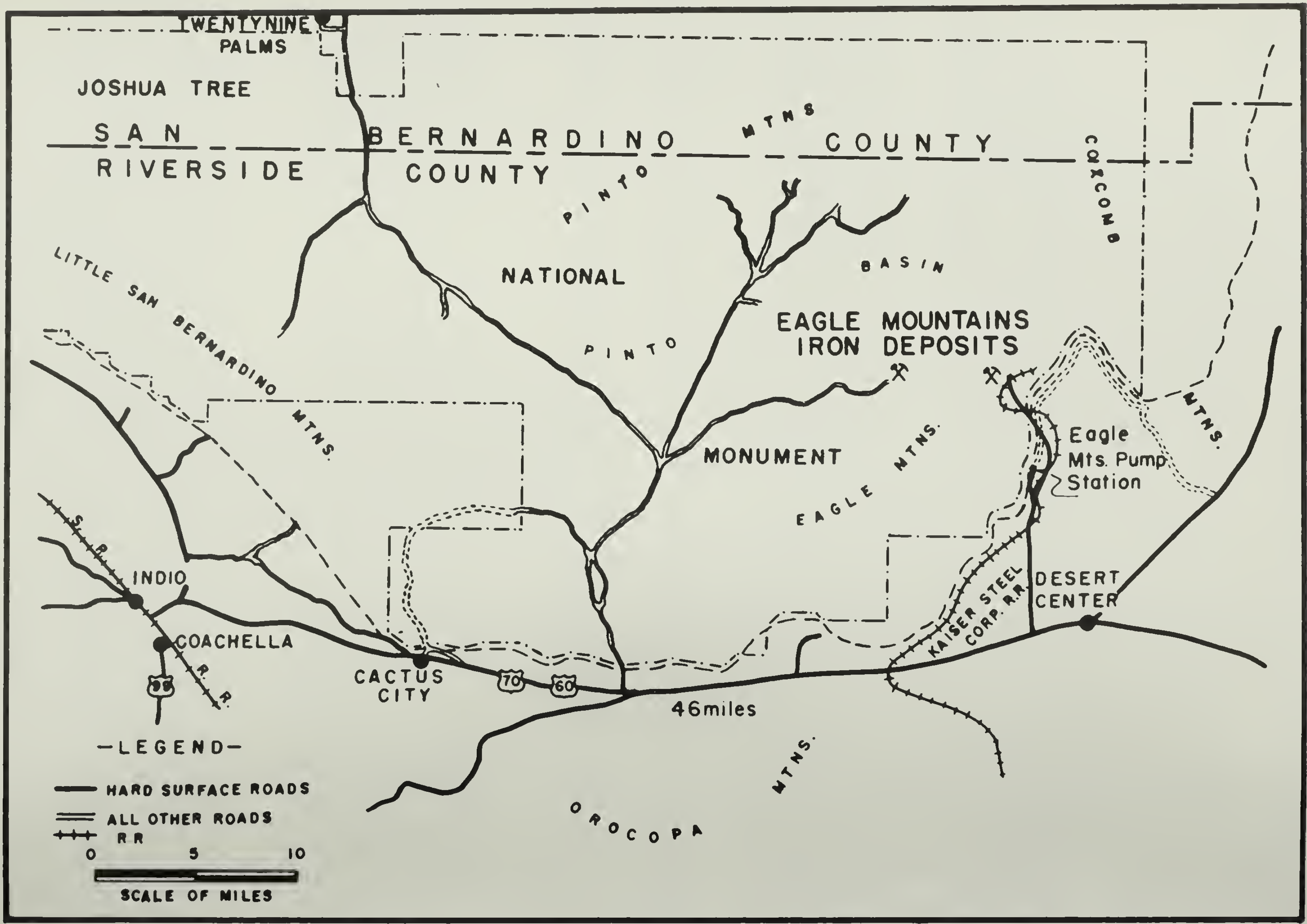

Figure 1. - Location map.

Figure 2. - Plan map of Eagle Mountain mine, Riverside County, Calif.

Figure 3. - Upper location, Eagle Mountain, Calif.

Figure 4. - Aerial view, Eagle Mountain, Calif.

The Riverside Iron & Steel Co. of Pasadena, Calif., was organized in 1940 and obtained control of the Southern Pacific Land Co. claims. The company intended to erect several electric furnaces on the property to make higher grade iron by the Knowles process, as developed by the Corby Iron & Steel Co. in England, using petroleum coke as a reducing agent. These plans had to be abandoned because of the war, and the only production during World War II was approximately 60,000 tons of crude iron ore for ship ballast and shipment to the cement industry.

Under the Strategic Minerals Program, the Bureau of Mines, in conjunction with the Federal Geological Survey, started an exploration program September 8, 1941. This was completed May 16, 1942. Project work indicated the existence of a large tonnage of direct-shipping ore and a greater potential reserve of lower grade ore amenable to low-cost beneficiation.

In 1946 Kaiser Steel Corp., which was operating 1 blast furnace and 7 open hearths using 50- to 55-percent iron ore from Cedar City, Utah, and high-sulfur ore from the Vulcan mine, Calif., acquired the property. During 1947-48, a railroad was built from the property to the Southern Pacific Railroad at Ferrum, Calif.; a crushing plant and stockpiling and loading facilities were constructed. In the latter part of 1948 opencut mining was begun on the Bald Eagle deposit, and regular shipments of iron ore were made to the Fontana steel mills 164 miles away. In 1949 a second blast furnace of 1,200 tons daily capacity was added at Fontana, and a third blast furnace of 1,200 tons daily capacity was added in 1953.

ORE DEPOSITS[4/]

General Geology

The oldest formation in the northern part of the Eagle Mountains consists of gneiss, schist, and quartzite, with local thin layers of crystalline limestone. Next younger is a thick series of metamorphic sedimentaries, the lower part of which consists of massive vitreous quartzite, with thin-bedded and schistose feldspathic layers, whereas the upper part includes crystalline dolomite, quartzite, schist, lime-silicate rock, iron ore, and various metamorphic minerals.

These sedimentaries have been intruded by sill-like bodies of quartz monzonite. The deposition of the iron ore and the associated metamorphic minerals, serpentine, mica, amphibole, epidote, and pyroxene, followed the period of plutonic activity, these minerals having been introduced by deep-seated solutions that replaced the dolomite and probably parts of the more impure quartzites. A period of uplift and tilting followed mineralization, accompanied by considerable faulting, which displaced the sediments (including the ore beds) as much as 300 feet vertically. Still later fine-grained dikes 1 to 40 feet wide were intruded, many of which cut the ore formations.

In the eastern part of the district 2 beds of ore extend east and west for about 2 miles, with an average dip of 40° N.; they are separated by 200 to 250 feet of quartzite and lime-silicate rock. The iron and associated metamorphic minerals have completely replaced the beds of dolomitic limestone in this part of the district; but farther west the ore occurs in bands or irregular masses within the dolomite, roughly following the bedding of the latter.

4/ Bureau of Mines, Eagle Mountains Iron District, Calif.: War Min. Rept. 97, 1943, pp. 20-22.

Size, Shape, and Distribution

The principal ore deposits of the Eagle Mountains occur in the northern part of the metamorphic sedimentaries, within which two horizons of dolomitic limestone have been irregularly replaced by iron ore. These 2 beds are separated by a belt of quartzite that is 500 feet thick in places. Because of their origin, the ore bodies generally follow the natural irregularities of the replaced sediments and range from 1 to 350 feet in thickness and 25 to 3,000 feet in length. The average strike is east-west, and the average dip is 40° N. The lateral extent of the ore bodies is not sharply defined, the high-grade ore grading into serpentine-magnetite rock or impure altered quartzite and lime silicate.

One of the largest deposits in the district occurs at the east end in an area along the ore-bearing zones having a maximum width of 1,600 feet and a length of 7,500 feet. Three deposits occur in this area, the largest being in the upper, or northern, ore bed; the other two are on the east and west sides, respectively, of Bald Eagle wash in the lower or southern ore zone. These three deposits were explored by the Bureau of Mines and are now designated by the Kaiser Steel Corp. as the North Ore Body, South Ore Body, and Bald Eagle. Except for several hundred thousand tons of ore, the Bald Eagle deposit has been depleted of open-pit ore and will receive no further consideration in this report. Table 1 gives data of size and shape of the North Ore Body and the South Ore Body.

TABLE 1. - Size and shape of the North Ore Body and South Ore Body

	North Ore Body, feet	South Ore Body, feet
Strike length..................	5,200	2,600
Length explored................	1,400	2,200
Maximum width across outcrop....	450	300
Maximum thickness normal to dip.	325	80
Average thickness normal to dip.	250	60
Average dip....................	45	30
Depth, Bureau of Mines exploration on dip..................	500	1,200
Probable depth on dip..........	850	1,800

In the remainder of the district there are about 60 other deposits ranging in length from 150 to 1,500 feet and in maximum width of outcrop from 30 to 250 feet. Of these 27 have an outcrop of 20,000 to 100,000 square feet each, with a total area of 943,000 square feet; 4 deposits have an outcrop of over 100,000 square feet each, the total area of these being 616,000 square feet.

THE ORE

The principal iron minerals are hematite and magnetite. The former occurs as a secondary mineral after pyrite and magnetite, although some small bodies of coarsely crystalline specular hematite are of primary origin. Near the surface and in the upper 100 feet of the ore beds, hematite predominates over magnetite in the ratio of about 5:1, but at depth magnetite, generally associated with pyrite, is the predominant ore mineral.

The highest grade ore is either a hard, dense, red hematite varying in texture from coarsely crystalline to finely granular or a hard, coarsely crystalline magnetite.

The lower grades of ore are of 2 general types; 1 is a mixture of granular hematite and magnetite containing abundant disseminated silicates, and the other consists largely of magnetite in a gangue of serpentine, tremolite, and minerals of the mica and chlorite groups.

The ore in the North-South pit was divided into 2 categories, 30- to 50-percent iron (the iron content was lowered to 30 percent pending beneficiation) and plus-50-percent iron. Combined grades total 51,094,000 tons, assaying, before beneficiation, 50.7 percent Fe, 0.086 percent P, 12.18 percent SiO_2, 1.64 percent Al_2O_3, 1.87 percent CaO, 5.42 percent MgO, and 0.603 percent S. Waste to be stripped to permit extracting this ore totals 19,672,000 cubic yards. The ratio of the ore to stripping will be 1 ton of ore to 0.385 cubic yard of waste.

METHODS OF PROSPECTING AND EXPLORATION

Exploration by the Bureau of Mines comprised trenching, diamond drilling, and underground exploration by adits, shafts, and raises. The general plan was a combination of surface trenching and core drilling both on lines 200 feet apart and at right angles to the strike of the beds; the holes were so spaced and directed on these lines as to cut the ore beds at 200 and 400 feet on the dip.

Trenches averaging 2 feet in width were dug by hand across the outcrops, jackhammers with moils being used to get down to the solid ore. The bottoms of the trenches were cleaned thoroughly with compressed air before sampling. Samples weighing about 20 pounds per linear foot were then cut in 5-foot sections, crushed to pass 1/2 inch, quartered, and shipped to Lerch Bros., Hibbing, Minn., who made all analyses for the project. Drill holes were sampled in 5-foot sections unless the formation changed definitely or it became necessary to stop drilling and cement the holes in crevices or broken ground.

Ordinarily the only analyses on core and sludge samples were for iron and sulfur. Composite sludge samples were collected for each hole and analyzed for iron, sulfur, and phosphorus, and representative composite sludges for each deposit were completely analyzed.

This exploration by the Bureau of Mines, with the assistance of the Federal Geological Survey, was preliminary and not intended for close control, such as is required in drawing mining plans and supplemental drilling was necessary. This drilling explored both east and west ends along the strike. To obtain greater depth on the dip, additional drilling was done from a tunnel at a lower elevation.

Supplementing the 6,700 feet of trenching, 14,500 feet of diamond drill, and 485 feet of underground exploration by the Bureau of Mines, the Kaiser Steel Corp. completed an additional 1,000 feet of trenching, 17,000 feet of diamond drilling, and about 3,000 feet of underground exploration. The combined results of all exploration work were used in completing the current mine plans for the North Ore Body and the South Ore Body.

To aid in exploring and developing the balance of the property, an aerial survey was completed with pictures and topographic maps on a scale of 400 feet to the inch at 25-foot contour intervals.

Before the company drilled a magnetometer survey of about 3,500 setups was made. When correlated with previous drilling and geology, this work made spotting of proposed diamond-drill holes for a pit plan comparatively simple.

The underground exploration work by the company comprised 2,826 feet of tunnel to get greater depth under the main exposure, which was drilled by the Bureau of Mines. This was driven in two parts - parallel to and in the footwall of the North Ore Body; both flanks of both ore bodies were exposed on the east and west ends. Topography and formation were ideal for such work. The west entrance began at the 1,390-foot elevation and was driven 1,277 feet, and the east entrance began at the 1,250-foot elevation and was driven 1,549 feet. Headings were connected by a 153-foot raise. Diamond-drill stations were cut at 200-foot intervals, or closer where needed in geologically doubtful areas, and holes were drilled. Both ore bodies could be reached for exploring from the tunnel. Sixty holes were drilled from underground and surface stations.

PLANNING OPEN-PIT MINING

Before mining plans could be developed, a field survey was necessary to obtain all of the geological and topographic data. To obtain this information, the Kaiser Steel Corp. set up a triangulation system of primary and secondary controls. This system was tied into a carefully measured baseline on the property.

As a control for the mapping of the area over each ore deposit, a baseline was staked along the strike of the outcrop and tied in to the triangulation system. Cross-section lines were then run at 100-foot intervals at right angles to and tied in to the baseline. These cross sections were projected well beyond the foot and hanging walls of the ore body to allow for stripping limits. A survey was then made along all sections, obtaining the elevations and locations of all contacts, faults, dikes, trenches, drill holes, and surface topography. This information was plotted on plan maps and cross sections.

A mining plan was developed by working from the cross sections and then projecting the work into a horizontal mining plan (fig. 2) showing the outline of the pit, the bench elevations, grade and tonnage by benches, and cubic yards or tonnages of stripping, including waste by benches and waste disposal area adjacent to pit. On each section is drawn a tentative pit slope needed to extract the ore shown on the sections. In addition to the information plotted on the sections obtained from the surface survey and drill holes, the shape of the ore body, waste intrusions, vein splits, and fault displacements were outlined on the sections.

The pit slope on the hanging-wall side of the North Ore Body is one-half horizontal to 1 vertical, with a berm 30 feet wide added each 90 feet vertically (fig. 5). To obtain an efficient mining plan with a minimum of sharp curves, which makes for easy work and safety, some pit slopes on the sections may have to be moved either to the left or right, keeping in mind the ratio of waste to ore, the fracture zones, and the strike and dip of faults. The objective is a workable plan for safely extracting maximum ore with minimum waste. The exploration work forms a reliable mining plan for extracting ore and can be followed without change from the highest to the lowest bench. Location of the pit scarp, berms, and benches, along with other pertinent data, such as grade of ore, amount on each bench, cubic yards of stripping waste, and elevations, are all known so that work can be planned.

USING THE PLAN IN THE OPERATION

Triangulation stations, established within the pit as needed from stations outside the pit area, makes it easy for the engineers to stake out the toelines and elevations for the various benches. The toelines are spotted before the blast holes are drilled. Having a definite mining plan enables the operator to locate the

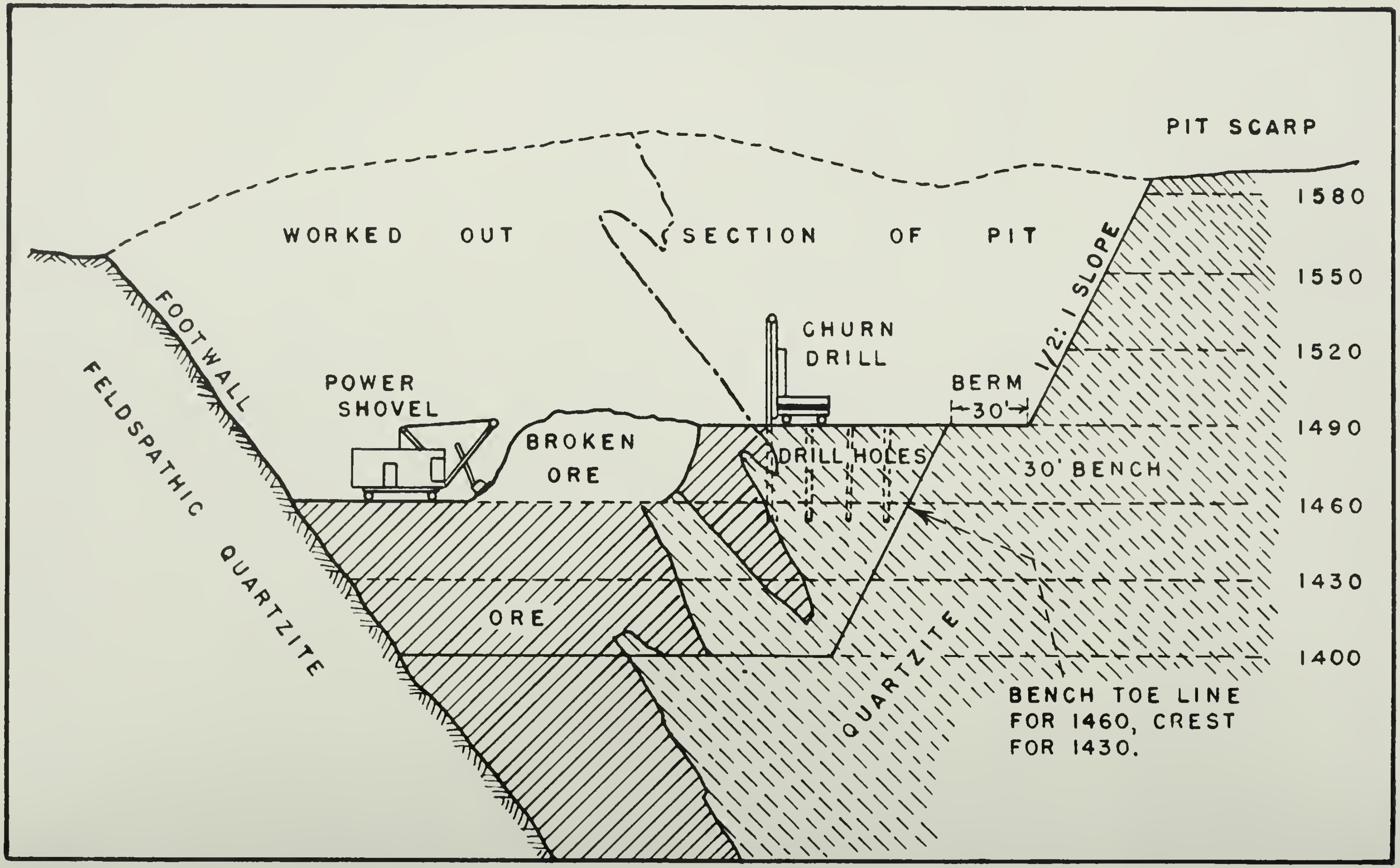

Figure 5. - Typical ore section in the North Ore Body, showing bench, berm, and slope arrangement.

crusher to handle maximum tonnage with minimum hauling, to dispose of the waste in the most efficient manner, to mine ore, to make certain grades, and to know the ratio of ore to waste. The last is essential in determining the cost per ton of ore mined.

MINING PLAN FOR NORTH ORE BODY AND SOUTH ORE BODY

Current operations begun in 1952, are on two ore bodies known as the North Ore Body and the South Ore Body, which will be mined in one pit. The pit will be 4,600 feet long, 2,000 feet wide at the widest point, and 660 feet from the highest elevation to the pit floor. It will have 22 benches, each 30 feet high. These benches will provide for mining and stripping the two ore bodies.

A truck-haul road 70 feet wide was constructed on a 7-1/2- to 8-percent grade from the west end of the pit to the top bench elevation at 1,710 feet on the north boundary of the North-South pit (fig. 2). In laying out the haul road it was planned so that the top 10 benches would intersect the bench elevation within the pit limits. Three benches will be mined simultaneously, and work on each will be timed to the requirements of ore and the need for stripping. Work on each bench is begun at the intersection of the road and the bench elevation.

The primary crusher is set at the 1,500-foot elevation, which will permit mining over 15 million tons of ore before moving to a lower elevation. Ore is trucked down grade to the crusher, and waste is either trucked down grade to waste dumps or level across benches to the footwall dump. Length of haul for ore and waste varies from 500 feet to 2,600 feet. The ratio of ore to stripping will be 1 ton of ore to 0.385 cubic yard of waste. At present, ore is being removed from 3 benches, the 1,590, 1,620, and 1,650.

DRILLING

Primary drilling, which represents almost 100 percent of all blast-hole drilling (only 25 boulders usually blasted per 14,000 tons of ore), is done mostly with 6 Bucyrus-Erie, diesel-driven, model 42-T churn drills (fig. 6). Two smaller churn drills, Bucyrus-Erie model 29-T, are used at times. All churn-drilling machines are mounted on crawlers. The holes are collared and drilled with a 9-inch, California-type, Mother Hubbard drill bit. The 42-T churn drill uses a 30-foot stem. When it is attached to the bit the assembly weighs 5,100 pounds. Heavy casing, 10-inch inside diameter, is driven to prevent caving of the hole near the collar. The length of casing depends upon the looseness of the material being drilled. Usually the casing varies from 6 to 8 feet in ordinary ground, but at times 20 feet of casing may be required. The churn-drill holes are spotted by the pit foreman. Two rows of holes are drilled parallel to the crest of the previous cut. The holes in each row of holes are spaced 15 feet apart. The rows of holes are spaced at 12 to 18 feet, depending upon the character of the ground to be drilled and whether the lower bench face has been cleared of broken material. If the lower bench face is covered with material, the row of holes nearest the crest or face of the previous cut is brought closer to the face than usual. The drilling speed of the 42-T churn drills varies from 6 to 12 feet per hour. All benches are 30 feet deep. The holes are drilled 37 feet deep. Water is added during the drilling as needed to supply the cuttings with enough fluid for good bailing and sampling. Overall cost for drilling is $0.90 per foot. There are two men to a drill crew. The 10-inch casing pipes are salvaged for reuse as the blasted material is removed.

Figure 6. - Bucyrus-Erie churn drill.

Jackhammers and wagon drills are used only when new benches are begun and for roadwork. Jackhammers and jacklegs are also used in drilling boulders preparatory to blasting. As this represents only a limited amount of drilling, portable compressors are used.

BLASTING

The explosives used in blasting the churn-drill holes are 45-percent nitro-starch, slow-speed, bag powder - 6,500 f.p.a. The primer is 75-percent stick powder, which is detonated by electric millisecond delay. Primacord is used when shooting single rows that are not adjacent to high banks.

The blasting foreman checks all holes for water and depth of hole. The dart value bailer is used to clean the hole. The bottom 1-1/2 to 2 feet of hole cannot be cleaned of cuttings; therefore the useful depth of a 37-foot hole is about 35 feet. The first operation in charging the hole is to lower the primer. In dry holes the primer consists of 2-1/2 pounds of 75-percent stick powder containing 2 electric blasting caps. In wet holes the primer consists of 6 pounds of 60-percent gelatin with 2 electric caps. After the primer is placed in the bottom of the hole, 350 to 450 pounds of bag powder is dumped in the hole if in ore. This allows not less than 24 feet of hole for the stemming, which is fine sand rejects from the beneficiation plant dumped at the collar of each hole with a Hydro Payloader. The stemming is not tamped. In a wet hole semigelatin powder in 4- by 24-inch stick form, is placed on top of the primer until the dry portion of the hole is reached; then the bag powder is used, as in a dry hole.

Waste requires 20 to 25 percent less powder than holes in ore. Explosives consumed in 1 year in both ore and waste averages 0.372 pound per ton of material broken. Secondary blasting, amounting to about 25 boulders in 14,000 tons, is done with stick dynamite and No. 6 electric blasting caps.

LOADING

The ore is loaded with four power shovels on crawlers. Two are Bucyrus-Erie, 54-B, diesel-driven shovels with 2-1/2-cubic yard dippers, and two are Bucyrus-Erie electric shovels (one 120-B with a 4-1/2-cubic yard dipper and one 150-B with a 5-cubic yard dipper, fig. 7). About 80 percent of the pit loading is done by electric shovels, assisted by a caterpillar dozer to level and keep truck haulageways clean. Together these shovels can handle 14,000 tons or more per 8-hour shift.

The large shovel operation is normally arranged so that the trucks can be loaded on both sides of the shovel (fig. 8). As one truck is loaded on one side of the shovel, another is in the loading position on the other side of the shovel. This requires a minimum of 80 feet of space to operate with the large shovel and 60 feet with the small shovel. The smaller shovels are ordinarily used to reload stockpiles, in pit areas too narrow for large shovels, and sometimes on road building. A fifth shovel - a 2-1/2-cubic yard, diesel-driven shovel - is used as a spare.

The shovel crew consists of 1 operator and 1 oiler. Electric power is conducted to the shovel by means of a heavy, three-conductor, safety cable which lies on the ground. The precautions taken for safety in the electric shovel operation are described under Safety Organization. Normal loading for a large shovel in ore is about 5,000 tons in an 8-hour shift and 6,500 tons in waste. Small shovels will load 3,500 tons in ore and 4,500 tons in waste.

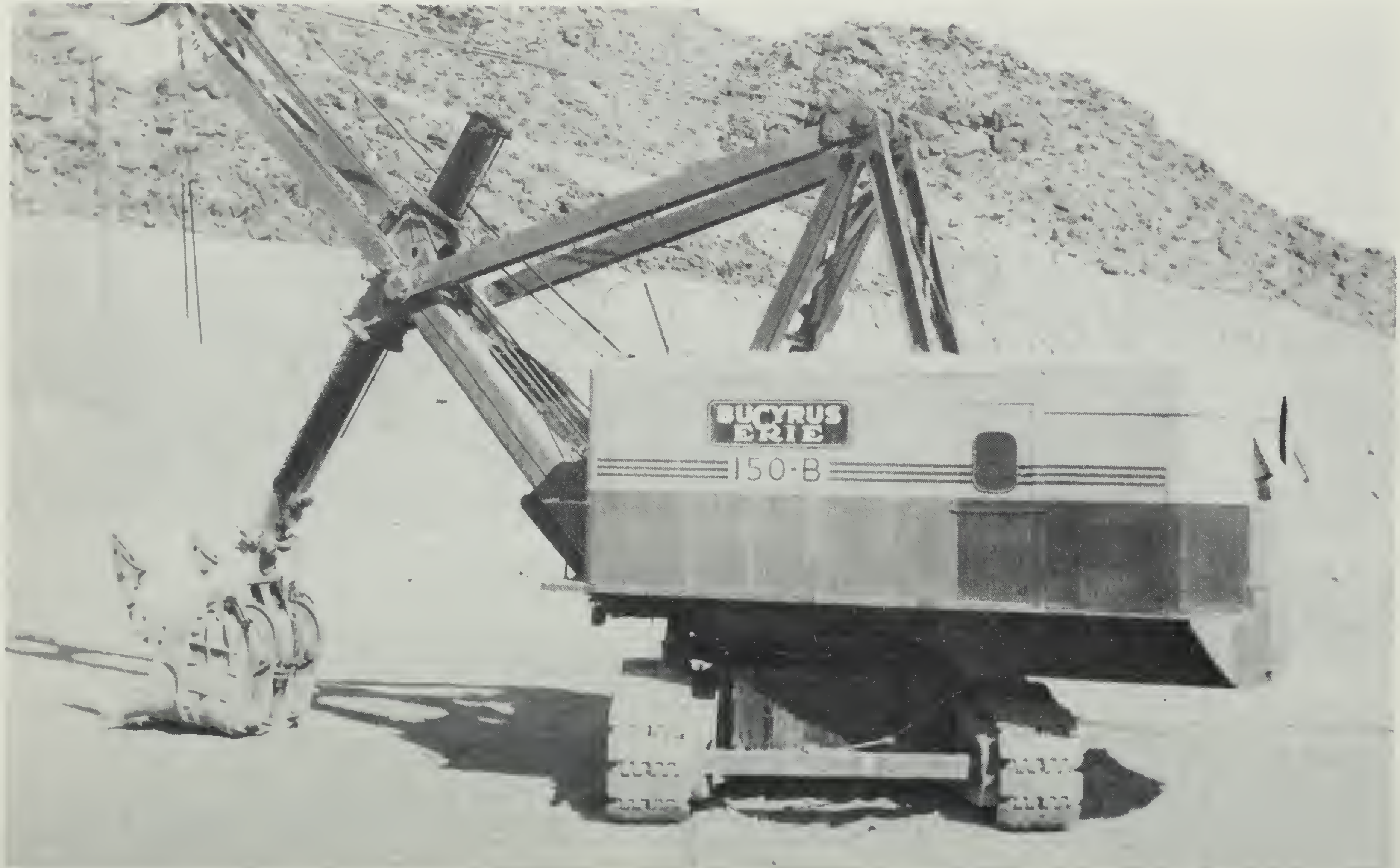

Figure 7. - Bucyrus-Erie 150-B electric shovel.

Figure 8. - Loading on both sides of shovel.

TRANSPORTATION

Ore and waste transported by trucks, principally Euclid, type 31, TD, diesel-driven units of 15-cubic yard capacity and Mack L. V. trucks of 15-cubic yard capacity, which replace the smaller type 27, FD Euclid now used only in emergency. Twenty trucks are available, but an average of 18 trucks works on a single-shift basis. Ten trucks are 15-cubic yard Euclids, 3 are 15-cubic yard Macks, and 7 are 10-cubic yard Euclids of the 2-axle, end-dump type. One Euclid, type 31, TD truck has an automatic transmission with two speeds - high and low. With the exception of this truck, all are equipped with Parkersburg Rig & Reel Co., 15-inch Hydrotarders mounted on the drive shaft between the 2 universal joints. A separate water system, including a 115-gallon steamoff tank, is mounted parallel to the truck frame. Power for the system pressure pump is taken off the drive shaft, and the control mounted on the dash is connected by linkage to the three-way valve. Truck speeds can be held to a safe 9 to 15 m.p.h. on 8-percent grades. Use of regular truck brakes is held to a minimum, and relines are required only after 3 to 4 years of service.

A different braking device is used on the Euclid, type 31, TD equipped with the Allison automatic transmission. The braking device is the new, in-the-drive-line Allison Torqmatic brake. The system uses oil for the braking fluid rather than water, as is used in the Parkersburg brake. The pumping action of the rotor circulates the oil to the heat exchanger. Here the water in the motor-cooling system dissipates the heat in the heat exchanger. With this system, the life of the service brakes is increased tremendously.

Experiments were made with various types of liners to protect the truck bodies. The most satisfactory and economical liner was found to be the A-R plate. In May 1952, 5 trucks were lined with A-R plate, a 1-inch, abrasive-resisting, steel plate having a 3-percent manganese content. The installation is rapid, and maintenance has been small.

The roads in the pits are 70 feet wide, and, although not hard surfaced, they are like a pavement. They are kept to grades of 8 percent or under with minimum radii of 150 feet on curves that have a superelevation of about 0.8 foot per 10 feet. The roads are sprinkled continuously, and a power blader is used daily to maintain smooth, dustless surfaces giving minimum tire wear.

Lengths of hauls vary from 500 to 2,600 feet. Truck speed is kept to about 15 m.p.h., loaded. Average per shift for a truck is about 900 tons of mixed ore and waste hauling.

At waste dumps a dumpman directs dumping, and at both waste dumps and shovel cuts the surfaces are leveled with Caterpillar dozers.

COST DATA

Operators are interested in production-cost figures. Table 2 shows the direct operating costs of the 3 major open-pit operations described above for a 12-month period. Since individual company accounting methods and locations vary, overhead, property taxes, interest, depreciation, and depletion costs have not been included; only direct cost for labor, maintenance repairs, and operating supplies per ton of crude ore mined are included. The costs shown are for a single shift working 21 days per month and producing 15,587 tons per day. There were 1,808,000 tons of ore and 2,120,000 tons of waste, a total of 3,928,000 tons worked during the month; a ratio of ore to waste of 1 to 1.73. The average truck haul was 1,800 feet.

TABLE 2. - Operating costs of major pit operations

	Costs per ton of crude ore mined				
	Labor[1/]	Repairs	Supplies	Special items	Total
				(Explosives)	
Drilling and blasting ..	$0.04	$0.01	$0.02	$0.06	$0.13
Shovel operation	.01	.02	.01	0	.04
				(Tires)	
Truck operation	.02	.02	.01	.01	.06
Total	$ .07	$ .05	$ .04	$ .07	$ .23

1/ Cost includes direct supervision, payroll tax, and insurance.

Ratio of ore to waste 1 to 1.173

Hourly wage rates paid for main job classifications are shown in table 3.

TABLE 3. - Wage rates of main job classification

Job classification	Hourly rate
Laborer	$1.85
Drillers:	
Jackhammer	2.00
Wagon drill	2.15
Churn drill	2.25
Heavy-duty truck driver	2.20
Mechanic's helper	2.00
Mechanic	2.35
Shovel operator	2.55

The organization personnel at the mine includes a general pit foreman, who is responsible for drilling, blasting, shovel, and trucking operations; a general foreman at the beneficiation plant, who is responsible for crushing, beneficiation, and ore shipping; a general foreman (railroad), who is responsible for train operation and maintenance of way; a master mechanic, who is responsible for maintenance of equipment and facilities (electrical and mechanical); a mine engineer, who is responsible for all engineering; and an office manager, who is responsible for accounting, payrolls, warehouse, and company store operation.

CRUSHING AND LOADING

At the 1,500-foot elevation in the North-South pit trucks dump into a 50-ton hopper (fig. 9) feeding directly into a 66- by 84-inch jaw crusher set to 7-1/2 inches (fig. 10). The crushed ore is transferred to a surge pile on a 60-inch belt conveyor. The surge pile has a capacity of 56,000 tons, of which 5,000 tons are considered live storage. In an emergency the balance of the surge pile could be moved into the drawpoint by bulldozers. From the surge pile the ore is drawn off through an underground reclaiming tunnel controlled at drawpoint by a 60-inch pan feeder discharging into a rock box on a 42-inch belt conveyor to the secondary crushing unit giving a 3-inch product. This product is taken to a third crusher in closed circuit with sizing screens to give a final product of minus-1-inch.

Provisions has been made to treat this material in a beneficiation plant (figs. 11 and 12), which is under construction. The process will be magnetic separation and heavy medium separation.

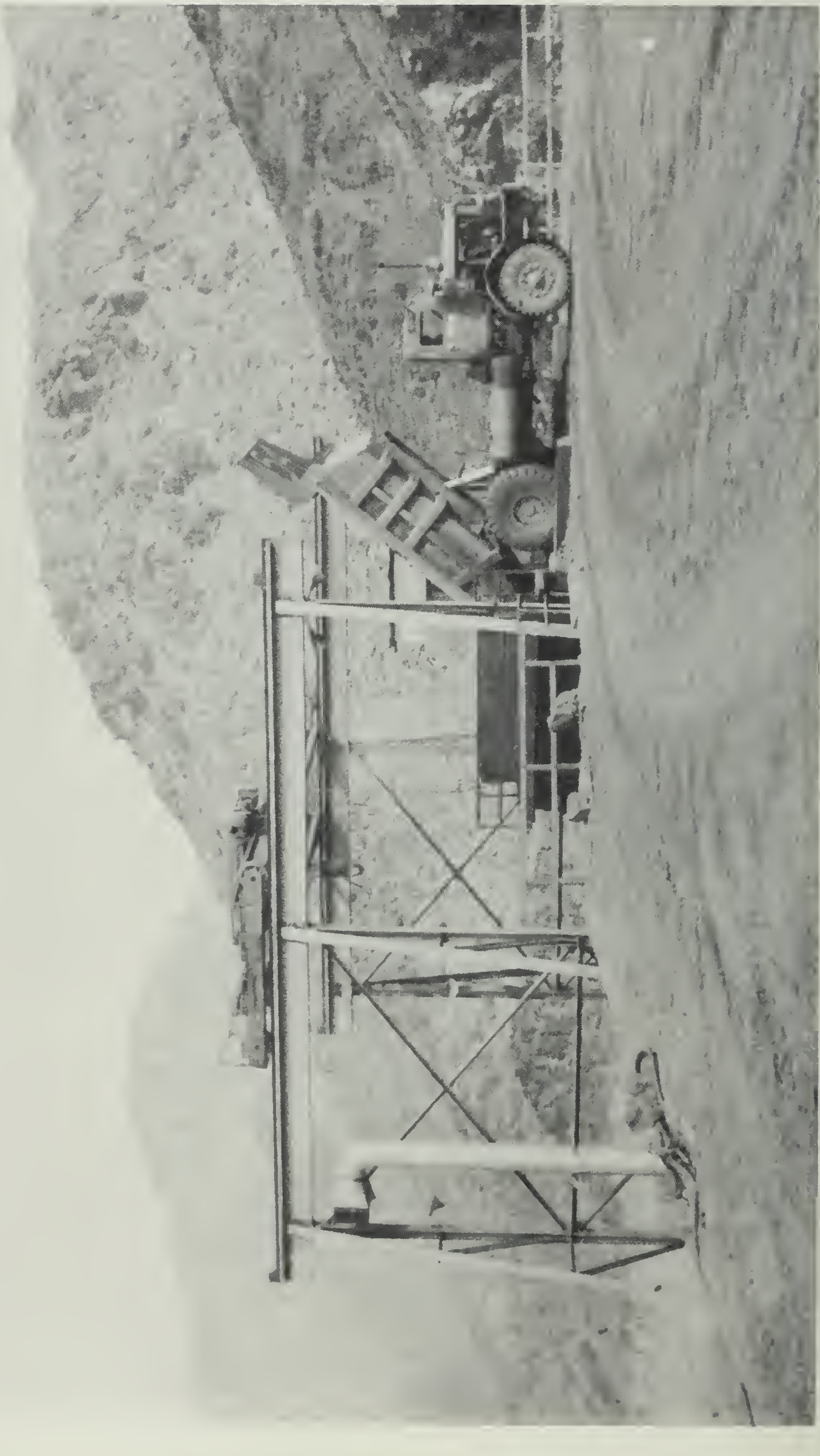

Figure 9. - Truck dumping into primary crusher.

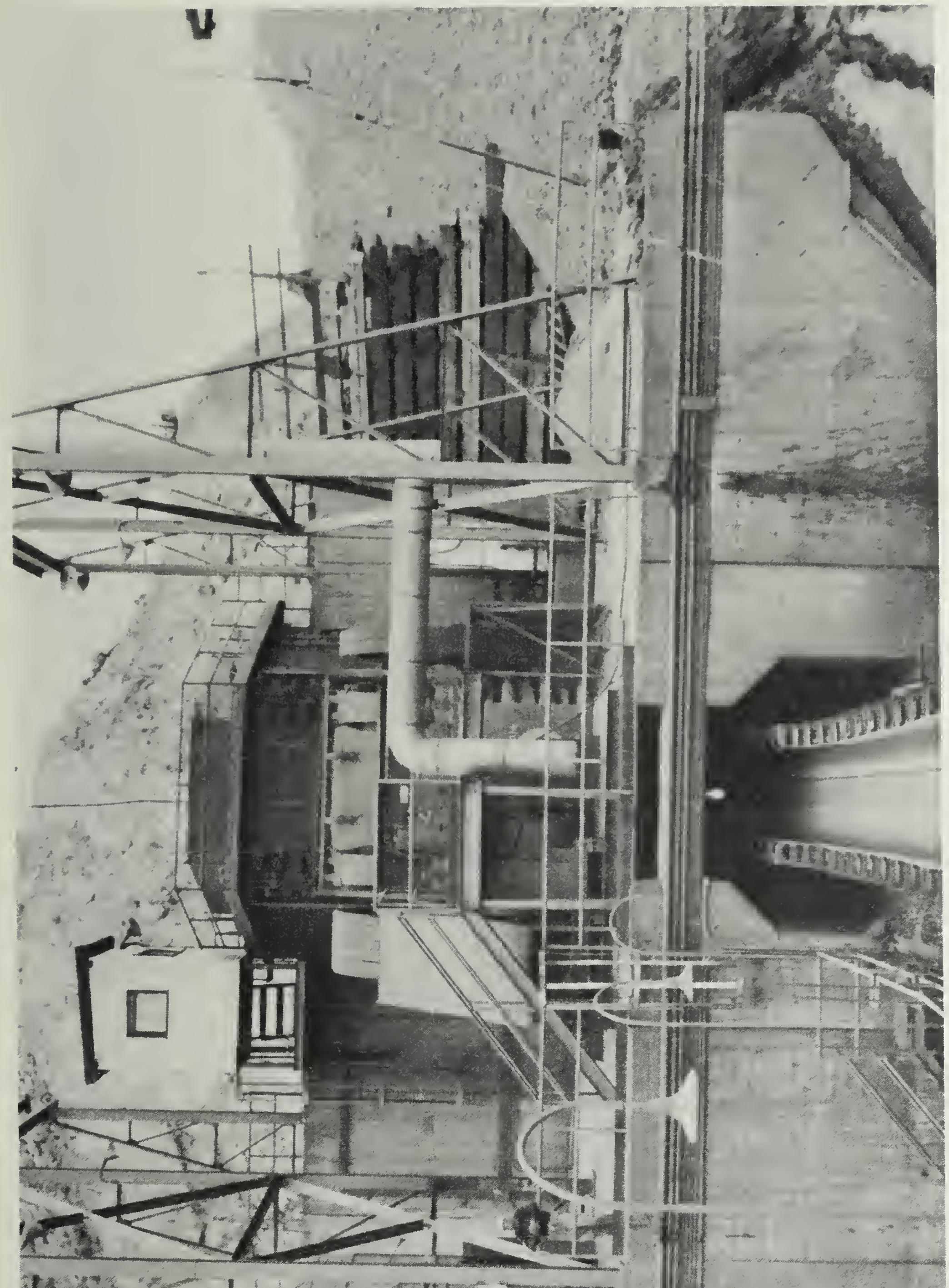

Figure 10. - Primary crusher.

Figure 11. - Secondary crusher and beneficiation plant, looking west from primary crusher.

Figure 12. - View looking east toward North and South pits; beneficiation plant in left background.

The shipping grades of ore are conveyed to stockpiles east of the loading tower. The ore is drawn off from a reclaiming tunnel underneath the stockpiles. It is controlled at the drawpoints by chute gates discharging on to a 42-inch conveyor belt. This ore dumps into an ore bin over a railroad scale (fig. 13). The belt and scale are operated by a weighmaster from a control tower near the truck.

SAMPLING

The churn-drill holes for blasting are sampled every 10 feet in ore. These analyses control the grade of the ore mined daily. The railroad cars are sampled at the Kaiser Steel Corp. plant at Fontana, Calif.

RAILROAD OPERATION

In 1946 and 1947 Kaiser Steel Corp. had a standard-gage railroad constructed under contract to connect the mine with the Southern Pacific Railroad at Ferrum, Calif., about 52 miles away. Ferrum is southwest of the mine and lies near the Salton Sea.

The railroad is a part of the overall mine operation. Four 1,600-horsepower, 150-ton, Baldwin, diesel-electric locomotives serve as power units for hauling 90 to 110 cars per day. The Southern Pacific Railroad supplies steel, gondola-type railroad cars of 62.5-ton capacity. Each round trip requires 7 to 9 hours. When the 3 blast furnaces at Fontana are in full production, 2 round trips per day of 70 cars each handle the required daily tonnage.

Ruling grade against the loads is 1.0 percent compensated; and is 2.15 percent compensated against the empties. Locomotives are equipped for multiple-unit operation and with electro-dynamic braking for the excessive grade.

DRAINAGE, WATER SUPPLY, POWER

Because of the topography there is no drainage problem in the open pit, and pumping is not required. Water is obtained from a well 9 miles by road north of the pit, pumped into tanks, and fed by gravity to the camp and pit. Power is obtained from the California Electric Power Co.

SAFETY ORGANIZATION

The safety engineer at the Fontana Steel plant visits the Eagle Mountain property monthly. The assistant superintendent conducts monthly safety meetings; all employees, including the mine superintendent and a safety supervisor, attend. Various safety topics are discussed, and the employees are requested to bring unsafe practices and unsafe conditions to the attention of the management. The various foremen hold safety meetings with their crews.

The foreman makes a written report on all accidents. The more serious accidents are investigated by a safety committee. They place the responsibility for the accident and decide on preventive measures to be taken and the proper disciplining of those considered responsible for the accident. The machinery is well guarded. Safety regulations, such as wearing hard hats, goggles, respirators, and hard-toed shoes, are enforced.

Safety bulletins obtained from the National Safety Council, the State Division of Industrial Safety, and the Industrial Indemnity Insurance Co. and special posters

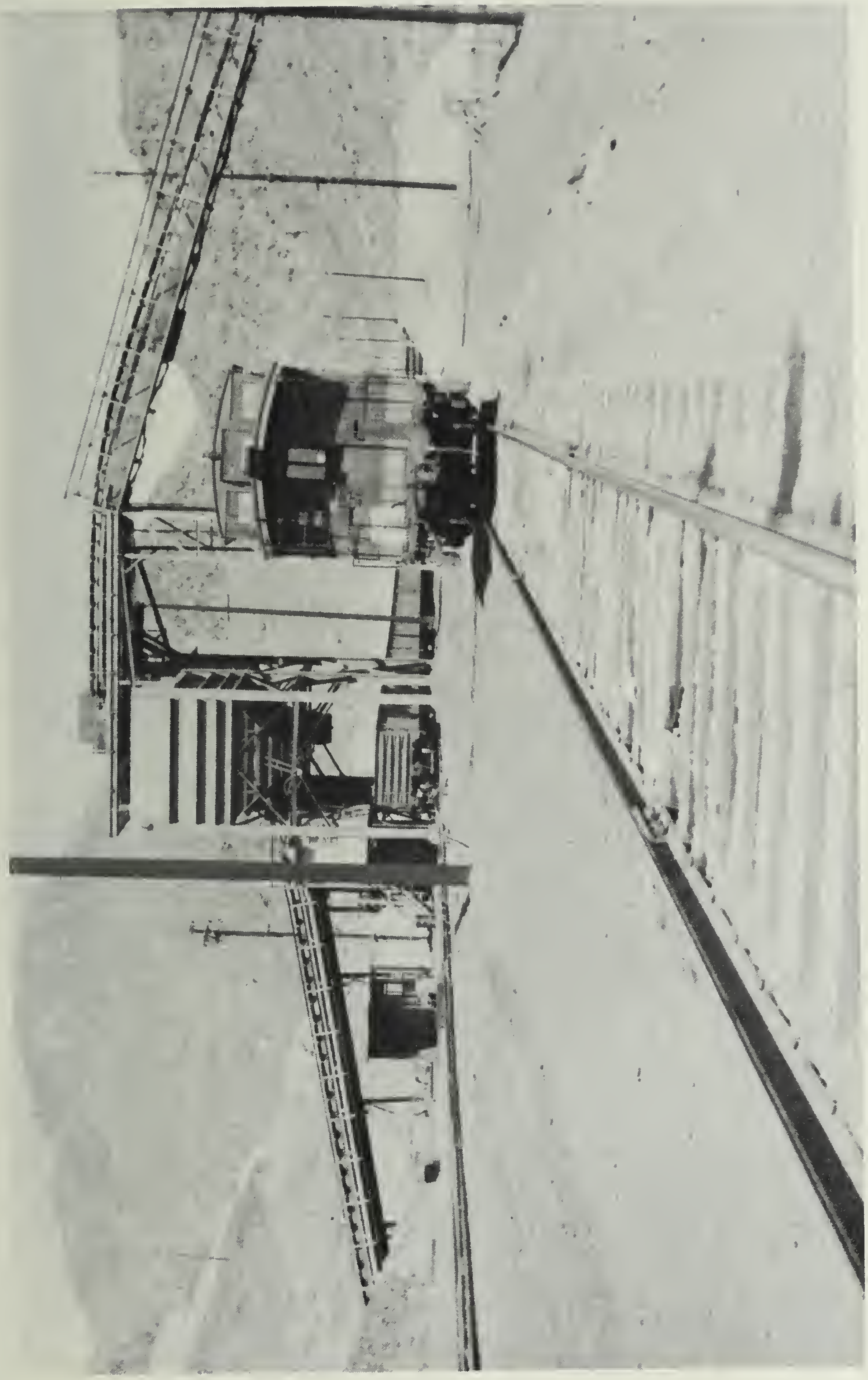

Figure 13. - Loading tower.

from the Elliot Service and others are displayed on safety bulletin boards in various departments. The safety bulletin board at the mine office shows the number of accidents each month, also the number of days without a lost-time accident (fig. 14).

Safety is stressed throughout the operation and particularly in electric-shovel operations. Each shovel circuit has a skid-mounted safety breaker. Power for the shovel passes through the breakers, and the shielded ground wire of the cable connects through a relay in the safety breaker box. A resistance to ground, which limits the current to from 15 to 20 amp., actuates the relay and opens the breaker switch, instantly cutting all power to the shovel. The breakers have justified their use on several occasions.

An overhead ground wire is carried as a fourth wire throughout the pit power-distribution system. A connection from the ground wire is carried to each of the power connection points together with the power wires. At all connection points, the power circuit passes through fused breakers and the ground wire is lugged for ease in connecting the power cable leads. The overhead ground wire, as mounted on top of the power poles, serves as a lightning arrestor.

The power-distribution system, serving the entire operation, has an additional safety factor. The system is divided into six separated sections by general areas served such as houses, shops, crushers, and pits. Built into each of these systems and located in the switching station are grounded transformers of the latest design. A ground in any section will instantly open breaker to the section and deenergize it. The State Industrial Accident Commission has complimented the operators for installing sectionalized ground protection. By sectionalizing the system, in case of failure by grounding only a small portion of the operation is effected.

For night operation, the pit roads are well lighted by flood lights mounted on high poles. Floodlights are installed on all shovels and also on the churn drills.

Employees volunteer for first-aid training given by the Bureau of Mines. As a result of the interest in safety from the top management down, the Kaiser Steel Corp. safety record for 1953, when compared with the safety record of the Nation's open-pit operations, is very good. The comparison is as follows:

	Kaiser Steel Corp.	National
Frequency rate	20.4	33.6
Severity rate	.1	4.02

Figure 14. - Safety bulletin board at mine office.

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Bureau of Mines
Information Circular 7736

PERMISSIBLE MINING-LOADING EQUIPMENT

BY H. B. BRUNOT

United States Department of the Interior — March 1956

PERMISSIBLE MINING-LOADING EQUIPMENT

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. . . . **Information Circular 7736**

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
Thos. H. Miller, Acting Director

March 1956

PERMISSIBLE MINING-LOADING EQUIPMENT

by

H. B. Brunot 1/

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1/ Electrical engineer, Bureau of Mines, Pittsburgh, Pa.

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ILLUSTRATIONS

SUMMARY

On April 26, 1949, the Bureau first approved a machine designed to replace the cycle of cutting, blasting, and loading coal by a single operation. This machine took the coal directly from the solid face and delivered it to transportation equipment. By January 1, 1955, 30 approvals for designs of machines of this type had been granted by the Bureau.

In the main, this paper describes briefly the action of the various designs approved as permissible. In addition, the approval number, the date of approval, the voltage of the power supply, the number and character of the explosion-proof accessory parts, the size of the trailing cable, and the overcurrent protection at the outby end of the trailing cable are given for each design.

Since no similar information has been published by the Bureau, it is hoped the material in this paper will be valuable in giving the mining public an organized look at the various machines of this nature that have been approved as permissible by the Bureau.

INTRODUCTION

The Bureau of Mines investigates and approves equipment as permissible for use in gassy and dusty mines only when it meets certain minimum standards of safety. These standards are designated as schedules; they establish certain minimum requirements of safety and give details of inspections and tests adopted to determine whether the standards have been met and list the charges for such investigations by the Bureau. Any responsible party can submit his equipment for investigation in accordance with the conditions outlined in the schedules. After the effective date of Public Law 552, all new electric equipment for operation in the face regions of gassy mines employing more than 14 persons underground is required by Federal law to be approved by the Bureau as permissible. Before the passage of this law, the use of such equipment was voluntary except where required by State law.

The first electric-motor-powered machines tested by the Bureau of Mines for safety in gassy and dusty coal mines were shortwall coal-cutting machines, and the first machine approved as permissible was a shortwall coal-cutting machine. This approval was dated September 30, 1914, and was granted under the provisions of Schedule 2. Since approval of Schedule 2 by the Secretary of the Interior on October 26, 1911, several revisions of the requirements have been made. Those revisions in effect when the machines described in this publication were approved were contained in Schedule 2E.

Machines for operation at the coal face have been steadily improved and the varieties of designs have greatly increased during the years. Thus, various types of coal-cutting machines, coal-loading machines, conveyors, etc., have been developed, and their designs have been investigated and approved as permissible by the Bureau. The latest developments have produced machines designed to replace the cycle of cutting, blasting, and loading. They take the coal directly from the solid face and deliver it to conveyors, shuttle cars, or other transportation equipment in one operation.

Thirty designs of these so-called continuous miners have been approved as permissible by the Bureau. This paper describes briefly each design approved by the Bureau. Descriptions of the detail features of the various explosion-proof parts used on the various machines will not, in general, be given.

APPROVED MACHINES BUILT BY JOY MANUFACTURING CO.

General Description

The Joy Manufacturing Co. continuous mining machines are mining and loading machines designed to take coal from the solid face and deliver it to a room-conveyor, shuttle car or other transportation equipment without undercutting, drilling, and shooting down the coal. In operation, the ripper head (see a, figs. 1, 2, 3, and 4) is sumped into the coal face, either at the top or bottom, depending on the design of head, and then swung vertically down or up, ripping the coal from the solid as it moves. The scrolls (see b, fig. 1) gather the loose coal to the center where it is picked up by the front conveyor of the machine. Two types of ripper heads have been used; the type shown in figures 3 and 4 has a number of parallel cutter chains carrying bits to rip the coal from the face. The type shown by figures 1 and 2 has a cutter chain at each side, with a rotating drum between them driven by the chains. Both the chains and the rotating drum carry bits to dislodge the coal from the face. The machines in figures 1, 2, and 4 are caterpillar-mounted for tramming. Caterpillar tracks are not used with the type 2WM machine shown in figure 3, the so-called Walking Miner, so that the machine will be low for thin-seam work. This machine is moved by a large base that supports the entire machine and four lift jacks that raise the machine for positioning of the base.

Four general types of permissible continuous mining machines have been built by the Joy Manufacturing Co. A number of modifications of the various general types have been approved. Aside from the type 2WM machine, both direct-current and alternating-current designs have been covered. Only the direct-current 2WM has been approved by the Bureau. The type 3JCM (fig. 1) is for low seams; the type 4JCM (fig. 2), is for high seams; and the type 2WM (fig. 3) is for very low seams. The type 1CM (fig. 4) is slightly smaller than the type 4JCM but is designed for greater production.

Several electrical parts can be seen in the four figures. In some instances the same design of accessories is used on the different types, and in other instances the corresponding parts are of different design.

In figure 1 c is 1 of the 2 motors driving the ripper head, a headlight is at d, 1 of the 2 traction motors is at e, the hydraulic pump motor is at f, and the 2 rear conveyor motors are at g. In figure 2 b is 1 of the 2 motors driving the ripper head, c is the controller and resistance compartment, d is 1 of the 2 traction motors, e shows the 2 headlights, and the 2 rear conveyor motors are at f. In figure 3 b is the controller on the machine, c is a headlight, d is a headlight resistance box, e shows the two conveyor motors, and f is the skid-mounted remote-control compartment. In figure 4 b is a main motor, c is a traction motor, d is a rear conveyor motor, e is the master switch, and f shows two headlights.

Details relating to the various designs, for which 14 approvals have been granted, follow:

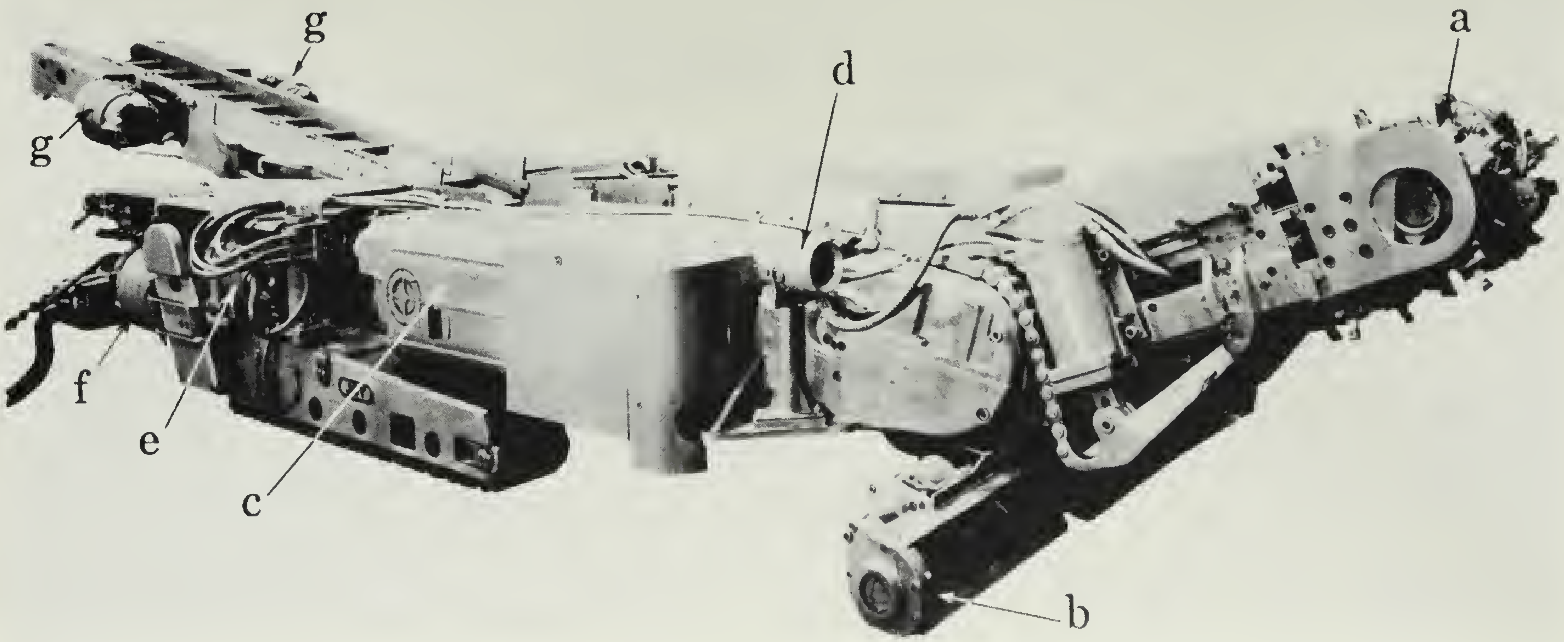

Figure 1. - Joy type 3JCM machine.

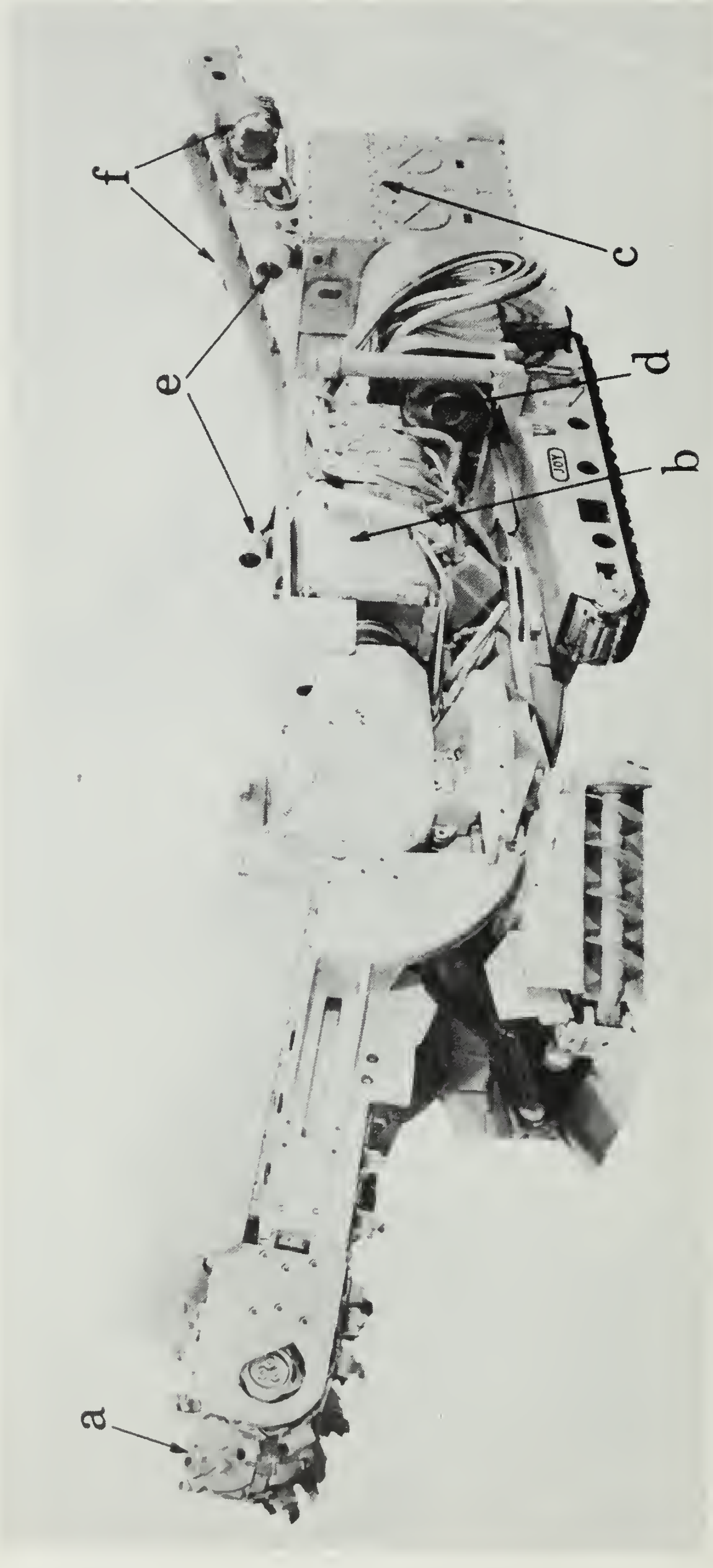

Figure 2. - Joy type 4JCM machine.

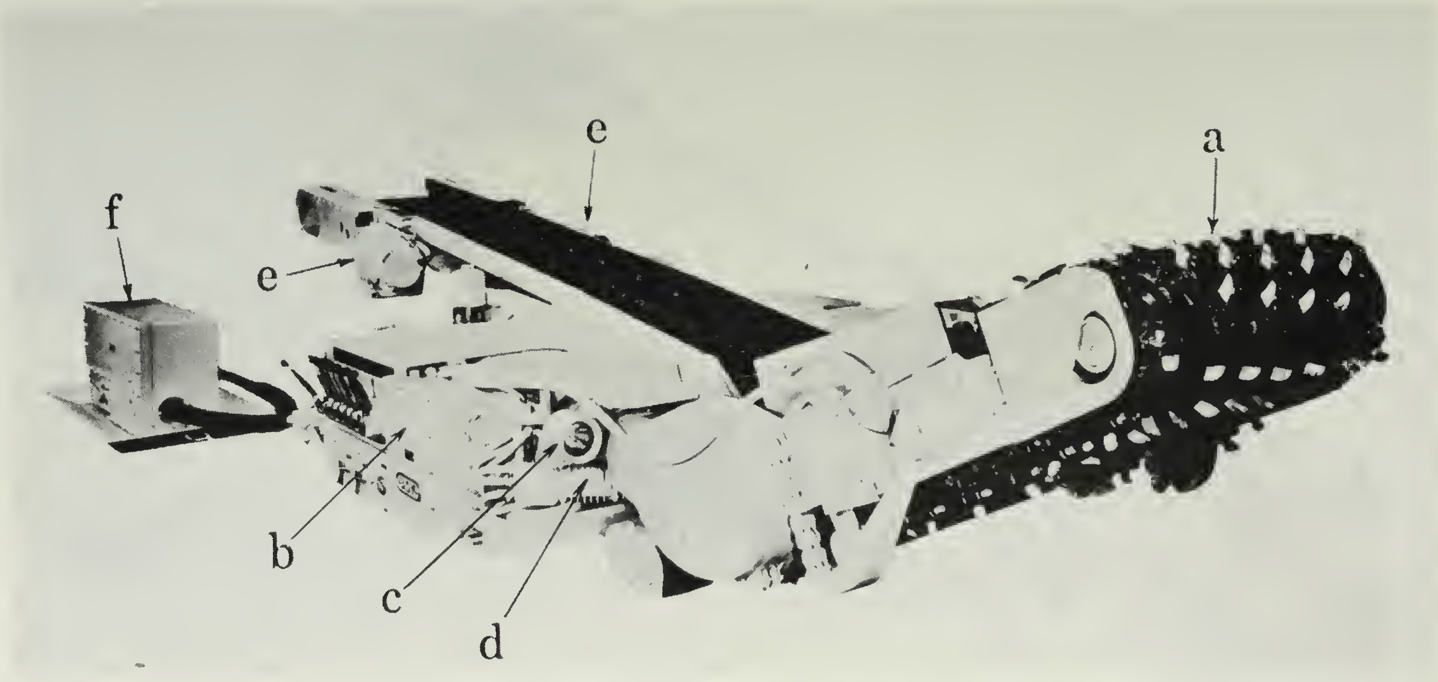

Figure 3. - Joy type 2WM machine.

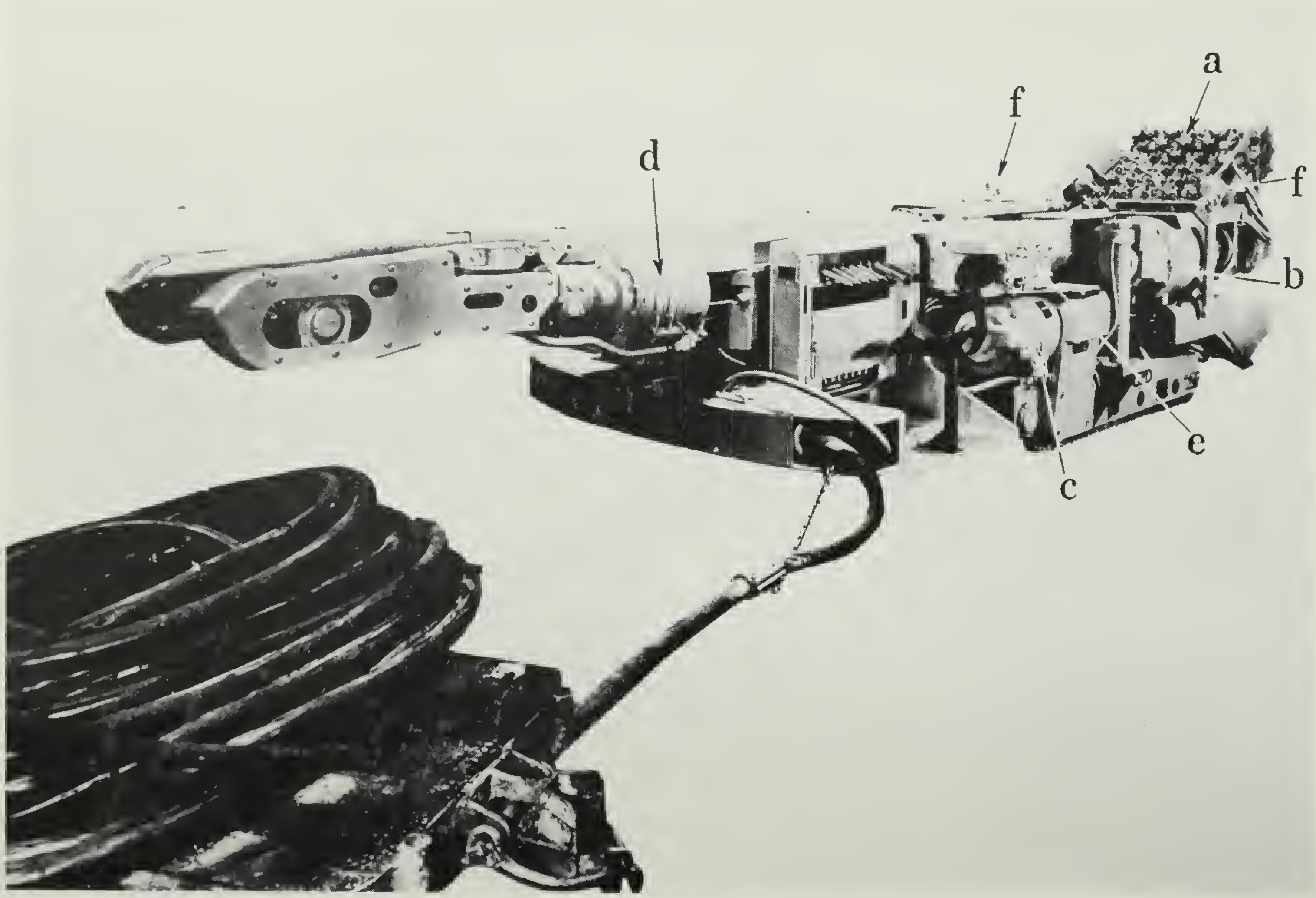

Figure 4. - Joy type 1CM machine.

Type 3JCM-2 D.-C. Continuous Miner

Approvals 2-666 and 2-666A, covering the design of the type 3JCM-2 continuous miner, were issued to the Joy Manufacturing Co. on April 26, 1949. The approvals apply to machines for operation from 250- and 500-volt, direct-current supplies.

Seventeen parts on this machine, as originally approved,were required to be explosion-proof: (1) A controller and resistance compartment; (2) two 65-horsepower motors; (3) three 7-1/2-horsepower motors; (4) two 5-horsepower motors; (5) 2 connection boxes, 1 on each 65-horsepower motor; (6) a master switch; (7) 2 headlights; (8) a headlight switch compartment; (9) 2 headlight resistance compartments; and (10) a trailing-cable connection box. In addition to the parts listed, several connection boxes that were not required to be explosion-proof by the Bureau's schedule were explosion-proof also.

The wiring between the various electrical parts is protected from mechanical injury by conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machines through 300 feet of 3-conductor, flame-resistant cable, No. 2/0 for 250 volts and No. 2 for 500 volts. One conductor is used for a frame ground connection. The cable was protected at the outby end by a circuit breaker set at 1,500 to 1,800 amperes for 250 volts and 1,000 to 1,200 amperes for 500 volts. An insulated mechanical strain clamp prevents strains on the terminal connections at the machines.

The type 3JCM-2A continuous miner was added by extensions of approvals under date of May 5, 1949. The principal differences from the 3JCM-2 machine are that a changed trailing-cable connection box incorporating the headlight switch is used, and the separate headlight switch compartment is eliminated. Also, the size of the trailing cable is increased to No. 4/0 for 250-volt and No. 2/0 for 500-volt machines.

Type 4JCM-1 D.-C. Continuous Miner

Approvals 2-675 and 2-675A, covering the design of the type 4JCM-1 continuous miner, were issued to the Joy Manufacturing Co. on July 1, 1949. The approvals apply to machines for operation from 250- and 500-volt, direct-current supplies.

Sixteen parts on this machine, as originally approved, were required to be explosion-proof: (1) A controller and resistance compartment; (2) two 65-horsepower motors; (3) three 7-1/2-horsepower motors; (4) two 5-horsepower motors; (5) 2 connection boxes, 1 each of the 65-horsepower motors; (6) a master switch; (7) 2 headlights; (8) a headlight switch compartment; and (9) 2 headlight resistance compartments. In addition to the parts listed, some connection boxes that were not required to be explosion-proof by the Bureau's schedule were explosion-proof also.

The wiring between the various electrical parts is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machine through 300 feet of 3-conductor, flame-resistant cable, No. 2/0 for 250 volts and No. 2 for 500 volts. One conductor is used for a frame-ground connection. The cable is protected at the outby end by a circuit breaker set at 1,500 to 1,800 amperes for 250 volts and 1,000 to 1,200 amperes for

500 volts. An insulated mechanical strain clamp prevents strains on the terminal connections at the machine.

Type 4JCM-1A D.-C. Continuous Miner

Approvals 2-734 and 2-734A, covering the design of the 4JCM-1A continuous miner, were issued to the Joy Manufacturing Co. on May 22, 1950. The approvals apply to machines for operation from 250- and 500-volt, direct-current supplies.

Sixteen parts on this machine were required to be explosion-proof: (1) A controller and resistance compartment; (2) two 65-horsepower motors; (3) three 7-1/2-horsepower motors; (4) two 5-horsepower motors; (5) 2 connection boxes, 1 on each of the 65-horsepower motors; (6) a master switch; (7) 2 headlights; (8) a headlight switch compartment; and (9) 2 headlight resistance compartments. In addition to the parts listed, some connection boxes that were not required to be explosion-proof by the Bureau's schedule were explosion-proof also.

The wiring between the various electrical parts is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machine through 300 feet of 3-conductor, flame-resistant cable, No. 4/0 for 250 volts and No. 2/0 for 500 volts. One conductor is used as a frame ground connection. The cable is protected at the outby end by a circuit breaker set at 1,500 to 1,800 amperes for 250 volts and 1,000 to 1,200 amperes for 500 volts. An insulated mechanical strain clamp prevents strains on the terminal connections at the machine.

Types 4JCM-1A and 4JCM-2 A.-C. Continuous Miners

Approvals 2-739 and 2-739A, covering the designs of the 4JCM-1A and 4JCM-2 continuous miners, were issued to the Joy Manufacturing Co. on June 12, 1950. The approvals apply to 4JCM-1A machines for operation from 220-, 440-, 380-, and 400-volt, alternating-current supplies. The 4JCM-2 machine was covered for operation from a 220-volt supply. The approval was extended under date of September 1, 1950, to cover machines for operation from 500-volt supplies.

Elevan parts on these machines were required to be explosion-proof: (1) A controller; (2) two 65-horsepower motors; (3) three 10-horsepower motors; (4) two 3-horsepower motors; (5) a master switch; and (6) 2 headlights. In addition to the parts listed, some connection boxes that were not required to be explosion-proof by the Bureau's schedule were explosion-proof also.

The wiring between the various electrical parts is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machine through 300 feet of 400,000-c.m., 3-conductor, type G, flame-resistant cable for 220 volts and No. 4/0, 3-conductor, type G, flame-resistant cable for the other voltages. The cable is protected at the outby end by a circuit breaker set at 2,000 to 2,500 amperes for 220 volts and 1,500 to 1,800 amperes for the other voltages. An insulated mechanical strain clamp prevents strains on the terminal connections at the machine.

Types 3JCM-2B and 3JCM-3 D.-C. Continuous Miners

Approvals 2-773 and 2-773A, covering the designs of the types 3JCM-2B and 3JCM-3 continuous miners, were issued to the Joy Manufacturing Co. on December 14, 1950. The approvals apply to machines for operation from 250- and 500-volt, direct-current supplies.

Sixteen parts on these machines were required to be explosion-proof: (1) A controller and resistance compartment; (2) two 65-horsepower motors; (3) three 7-1/2-horsepower motors; (4) two 5-horsepower motors; (5) 2 connection boxes, 1 on each of the 65-horsepower motors; (6) a master switch and connection-box compartment; (7) 2 headlights; (8) 2 headlight resistance compartments; and (9) a control station. In addition to the parts listed, some connection boxes that were not required to be explosion-proof by the Bureau's schedule were explosion-proof also.

The wiring between the various electrical parts is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machines through 300 feet of 3-conductor, flame-resistant cable, No. 4/0 for 250 volts and No. 2/0 for 500 volts. One conductor is used for a frame ground connection. The cable is protected at the outby and by a circuit breaker set at 2,200 to 2,500 amperes for 250 volts and 1,000 to 1,200 amperes for 500 volts. An insulated mechanical strain clamp prevents strains on the terminal connections at the machine.

Types 3JCM-2C and 3JCM-3C D.-C. Continuous Miners

Approvals 2-835 and 2-835A, covering the designs of the types 3JCM-2C and 3JCM-3C continuous miners, were issued to the Joy Manufacturing Co. on January 31, 1952. The approvals apply to machines for operation from 250- and 500-volt, direct-current supplies.

Thirteen parts (or 12 when a motor-generator is used to supply current for headlights) on these machines were required to be explosion-proof: (1) a controller and resistance compartment; (2) two 65-horsepower motors; (3) three 7-1/2-horsepower motors; (4) two 5-horsepower motors; (5) a master switch; (6) 2 headlights; and (7) 2 headlight resistance compartments. On 250-volt machines a motor-generator set may be used instead of the headlight resistor arrangement. In addition to the parts listed, some connection boxes that were not required to be explosion-proof by the Bureau's schedule were explosion-proof also.

The wiring between the various electrical parts is protected by hose conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machines through 300 feet of No. 4/0, 3-conductor, round or No. 4/0, 2-conductor, parallel, type G, flame-resistant cable for 250 volts and No. 2/0, 3-conductor round or No. 2/0, 2-conductor, parallel, type G, flame-resistant cable for 500 volts. One of the conductors in the round cable is used for a frame ground connection. The cable is protected at the outby end by a circuit breaker set at 2,200 to 2,500 amperes for 250 volts and 1,200 amperes for 500 volts. An insulated strain clamp prevents strains on the terminal connections at the machine.

Types 3JCM-2C and 3JCM-3C A.-C. Continuous Miners

Approval 2-845A, covering the designs of the types 3JCM-2C and 3JCM-3C continuous miners, was issued to the Joy Manufacturing Co. on March 24, 1952. The approval applies to machines for operation from 440- and 500-volt, alternating-current supplies.

Eleven parts on these machines were required to be explosion-proof: (1) A controller; (2) two 65-horsepower motors; (3) a 10-horsepower motor; (4) two 7-1/2-horsepower motors; (5) two 3-horsepower motors; (6) a master switch; and (7) 2 headlights.

The wiring between the various electrical parts is protected by hose conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machines through 300 feet of 3-conductor, No. 4/0, type G, flame-resistant cable. The cable is protected at the outby end by a circuit breaker set at 1,500 to 1,800 amperes. An insulated strain clamp prevents strains on the terminal connections at the machine.

Types 4JCM-1B and 4JCM-2B A.-C. Continuous Miners

Approval 2-861A, covering the design of the 4JCM-1B continuous miner, was issued to the Joy Manufacturing Co. on May 21, 1952. The type 4JCM-2B was covered by an extension of approval dated February 24, 1954. The original approval applied to machines for operation from 440- and 550-volt supplies. The extension of February 24, 1954, was for 440-volt machines.

Twelve parts on these machines were required to be explosion-proof: (1) A controller; (2) two 65-horsepower motors; (3) one 10-horsepower motor; (4) two 7-1/2-horsepower motors; (5) two 3-horsepower motors; (6) a master switch; (7) 2 headlights; and (8) a transformer compartment. (The option of using one 7-1/2-horsepower motor for the two 3-horsepower motors was allowed for the 4JCM-1B design by an extension of approval.) In addition to the parts listed, some connection boxes that were not required to be explosion-proof by the Bureau's schedule were explosion-proof also.

The wiring between the various electrical parts is protected by hose conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machine through 300 feet of No. 4/0, 3-conductor, type G, flame-resistant cable. The cable is protected at the outby end by a circuit breaker set at 1,500 to 1,800 amperes. An insulated strain clamp prevents strains on the terminal connections at the machine.

Type 4JCM-1B D.-C. Continuous Miner

Approvals 2-862 and 2-862A, covering the design of the type 4JCM-1B continuous miner, were issued to the Joy Manufacturing Co. on May 28, 1952. The approvals apply to machines for operation from 250- and 500-volt, direct-current supplies.

Thirteen parts (or 12 if a motor-generator set was used to supply current for headlights) on these machines as originally approved were required to be explosion-proof: (1) A controller and resistance compartment; (2) two 65-horsepower motors; (3) three 7-1/2-horsepower motors; (4) two 5-horsepower motors; (5) a master switch; (6) 2 headlights; (7) 2 headlight resistance compartments, or, on 250-volt machines a motor-generator set may be used instead of the headlight resistor arrangement. In addition to the parts listed, some connection boxes that were not required to be explosion-proof by the Bureau's schedule were explosion-proof also.

Later, under the date of July 11, 1953, hydraulic roof-bolting drills were added as optional on the 250-volt machine. A motor and a controller were added in connection with these drills.

The wiring between the various electrical parts is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machine through 300 feet of No. 4/0, 3-conductor, round, or No. 4/0, 2-conductor, type G, parallel, flame-resistant cable for 250 volts and No. 2/0, 3-conductor, round, or No. 2/0, 2-conductor, type G, parallel, flame-resistant cable for 500 volts. One conductor of the round cables is used for a frame ground connection. The cable is protected at the outby end by a circuit breaker set at 2,200 to 2,500 amperes for 250 volts and 1,000 to 1,200 amperes for 500 volts. An insulated strain clamp prevents strains on the terminal connections at the machine.

Type 3JCM-2B A.-C. Continuous Miner

Approval 2-868A, covering the design of the type 3JCM-2B continuous miner, was issued to the Joy Manufacturing Co. on July 16, 1952. The approval applies to machines for operation from a 440-volt, alternating-current supply.

Twelve parts on these machines were required to be explosion-proof: (1) A controller; (2) two 65-horsepower motors; (3) a 10-horsepower motor; (4) two 7-1/2-horsepower motors; (5) two 3-horsepower motors; (6) a control station; (7) a master switch and connection box compartment; and (8) 2 headlights. In addition to the parts listed, some connection boxes that were not required to be explosion-proof by the Bureau's schedule were explosion-proof also.

The wiring between the various electrical parts is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machine through 300 feet of No. 4/0, 3-conductor, type G, flame- resistant cable. The cable is protected at the outby end by a circuit breaker set at 1,500 to 1,800 amperes. An insulated mechanical strain clamp prevents strains on the terminal connections at the machine.

Type 2WM-1 D.-C. Walking Miner

Approvals 2-901 and 2-901A, covering the design of the type 2WM-1 walking miner, issued to the Joy Manufacturing Co. on January 28, 1953. The approvals apply to machines for operation from 250- and 500-volt, direct-current supplies.

Ten parts for these machines were required to be explosion-proof: (1) A controller; (2) two 65-horsepower motors; (3) two 5-horsepower motors; (4) 2 headlights; (5) 2 headlight resistance boxes; and (6) a skid-mounted, remote-control compartment.

The wiring between the various electrical parts is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machines as originally approved through a 25-foot length of cable from the supply to the skid-mounted controller. A 300-foot length of cable went from the skid-mounted controller to the controller mounted on the machine proper. The 25-foot cable was 3-conductor, 4/0 for 250 volts and 2/0 for 500 volts, flame-resistant cable. The 300-foot cable was the same as the 25-foot cable except that it was type G construction. An extension of approval has allowed a sectionalized cable between the 2 controllers for 250-volt machines. One section of cable has three 4/0 and three No. 10 conductors, whereas the other sections have three 4/0 and five No. 10 conductors. An intrinsically safe control circuit allows the sections to be coupled without explosion or fire hazard. Short-circuiting the 2 conductors in the last couple in connection, the intrinsically safe control circuit accounts for the 2 fewer conductors in 1 cable section. One of the conductors is used for a frame ground connection. The cables are protected by a circuit breaker set at 1,800 amperes for 250 volts and 1,000 amperes for 500 volts. Insulated strain clamps prevent strains on the terminal connections.

Type 1CM-1 D.-C. Continuous Miner

Approval 2-934, covering the design of the type 1CM-1 continuous miner, was issued to the Joy Manufacturing Co. on May 4, 1953. The approval applies to machines for operation from a 250-volt, direct-current supply.

Twelve parts on the machine as originally approved were required to be explosion-proof: (1) A controller and resistance compartment; (2) two 65-horsepower motors; (3) a 15-horsepower motor; (4) four 7-1/2-horsepower motors; (5) a master switch; (6) a motor-generator; and (7) 2 headlights. In addition to the parts listed, an explosion-proof meter and switch compartment was added by an extension of the approval. Some connection boxes that were not required to be explosion-proof by the Bureau's schedule were explosion-proof also.

The wiring between the various electrical parts is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machine through 300 feet of No. 4/0, 2-conductor, parallel, type G, flame-resistant cable. The cable is protected at the outby end by a circuit breaker set at 1,800 amperes. An insulated mechanical strain clamp prevents strains on the terminal connections at the machine.

Type 1CM-1 A.-C. Continuous Miner

Approval 2-971A, covering the design of the type 1CM-1 continuous miner, was issued to the Joy Manufacturing Co. on December 7, 1953. The approval applies to machines for operation from 440-volt, alternating-current supplies.

Eleven parts on this machine were required to be explosion-proof: (1) A control compartment; (2) two 65-horsepower motors; (3) a 15-horsepower motor; (4) two 7-1/2-horsepower motors; (5) two 3-horsepower motors; (6) 2 headlights; and (7) a master switch. In addition to the parts listed, some connection boxes that were not required to be explosion-proof by the Bureau's schedule were explosion-proof also.

The wiring between the various electrical parts is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machine through 300 feet of No. 4/0, type G, flame-resistant cable. The cable is protected at the outby end by a circuit breaker set at 1,500 to 1,800 amperes. An insulated strain clamp prevents strains on the terminal connections at the machine.

Type 1CM-2 D.-C. Continuous Miner

Approval 2-1007, covering the design of the 1CM-2 continuous miner, was issued to the Joy Manufacturing Co. on July 2, 1954. The approval applied to machines for operation from 250-volt, direct-current supply. The approval was extended under date of October 26, 1954, to cover machines for operation from 500-volt, direct-current supply.

Twelve parts on the machine as originally approved were required to be explosion proof: (1) A controller and resistance compartment; (2) two 65-horsepower motors; (3) a 15-horsepower motor; (4) four 7-1/2-horsepower motors; (5) a master switch; (6) 2 headlights; (7) a motor-generator; and (8) a meter and switch compartment. In addition to the parts listed, some connection boxes that were not required to be explosion-proof by the Bureau's schedule were explosion-proof also. The design for 500-volt operation allowed by extension of approval omits the motor generator and adds 2 headlight resistance compartments. Also, the two 65-horsepower motors were replaced by two 100-horsepower motors. A later extension of approval also allows 100-horsepower main motors on a 250-volt design.

The wiring between the various electrical parts is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machines through 300 feet of 2-conductor, No. 4/0, parallel type G, flame-resistant cable for 250 volts and 3-conductor, No. 2/0, flame-resistant cable for 500 volts. The cables are protected at the outby ends by circuit breakers set at 1,800 amperes for 250 volts and 1,000 amperes for 500 volts. Insulated mechanical strain clamps prevent strains on the terminal connections at the machines. Also, an extension of approval allowed a 3-conductor, No. 4/0 cable for a 250-volt design. One of the conductors of the 3-conductor cable is used for a frame ground connection.

APPROVED MACHINES BUILT BY THE JEFFREY MANUFACTURING CO.

Type 76-A D.-C. Colmol Mining Machines

Approvals 2-749 and 2-749A, covering the design of the Tyep 76-A Colmol mining machine, were issued to The Jeffrey Manufacturing Co. on August 8, 1950. The approvals apply to machines for operation from 250- and 500-volt, direct-current supplies. Figure 5 shows a late-type 76-A Colmol mining machine.

The 15 rotating breaker arms shown at the front of the machine in the picture are so arranged that every part of the coal face is covered. The arms carry cutter bits that break the coal from the face. The motion of the arms is toward the center of the machine at the bottom, so that the loose coal is swept to the center, where it is forced onto the conveyor as the machine advances.

The machine is powered by three 50-horsepower motors. Two of the motors are toward the front of the machine, one on each side, and they drive the breaker arms. The third motor furnishes power for all the other functions. All drives on the machine as originally approved were actually operated hydraulically by pumps and hydraulic motors.

As originally approved, this machine had 13 explosion-proof electrical parts: (1) Three 50-horsepower motors; (2) a control compartment; (3) 5 motor resistance compartments; (4) a headlight resistance; (5) 2 headlights; and (6) a rear light.

Some electrical parts of the machine illustrated can be seen, whereas others are obscured by various features. Thus, a motor is at a, the controller at b, and a resistance box at c.

The wiring between the various electrical parts is protected from mechanical injury by conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the 250-volt machine as originally approved through 2 lengths of 500 feet or less of 350,000-c.m., flame-resistant, single-conductor cable. A single-conductor, 4/0, flame-resistant cable was used for the frame ground wire. Power was conducted to the 500-volt machine through 500 feet or less of 3-conductor, 4/0 or 4/0 flat twin, type G, flame-resistant cable.

The cable was protected at the outby end by a 300-ampere, fused trolley tap for 500-volt machines and by a 600-ampere fuse in a small fuse box for 250-volt machines. An insulated mechanical strain clamp prevents strain on the terminal connections at the machine.

A number of optional arrangements have been allowed by the extensions of the original approvals - an emergency switch was added, options as to the number of lights have been allowed, the headlight resistance has been placed in a motor-resistance box, and the separate headlight resistance box was omitted in one design. Three designs use a mechanical instead of an hydraulic drive for the breaker arms. On these machines one motor-resistance box was used instead of a number, and an auto feed control compartment was added. In two of these machines a push button box is used to provide for dual control and the emergency switch is eliminated.

Figure 5. - Jeffrey type 76-A d.-c. Colmol.

Type 76-B D.-C. Colmol Mining Machine

Approval 2-808, covering the type 76-B design of the Colmol mining machine, was issued to The Jeffrey Manufacturing Co. on September 7, 1951. The approval applies to machines for operation from a 250-volt, direct-current supply.

In operation this machine is quite similar to the type 76-A machine described in connection with Approvals 2-749 and 2-749A. It is powered by three 70-horsepower motors. Two motors are toward the front of the machine, one on each side, and furnish power for driving the breaker arms. The third motor furnishes power for all the other functions. All drives on the machine as originally approved were actually operated hydraulically by pumps and hydraulic motors.

There were 7 explosions-proof electrical parts on this machine as originally approved: (1) Three 70-horsepower; (2) a control compartment; (3) a resistance compartment; (4) a light, and (5) an emergency switch.

The wiring between the various electrical parts is protected from mechanical injury by conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power was conducted to the machine through 2 lengths, 500 feet or less, of 500,000-c.m., flame-resistant, single-conductor cables. A single-conductor, 250,000-c.m., flame-resistant cable was used for the frame ground wire. The cable was protected at the outby end by two 400-ampere fuses in parallel in a small fuse box. An insulated mechanical strain clamp prevents strains on the terminal connections at the machine.

Two optional arrangements of the machine have been allowed by extensions of the approval. In the first of these a mechanical instead of a hydraulic drive was used for the breaker arms. On this optional design 2 resistance compartments, 2 lights, and 1 auto-feed-control compartment were used. The second optional arrangement was equipped similarly to the original design, except that 2 lights instead of 1 were used.

Type 76-B A.-C. Colmol Mining Machine

Approval 2-966A, covering the design of the type 76-B, alternating-current Colmol mining machine, was issued to The Jeffrey Manufacturing Co. on November 9, 1953. The approval applies to machines for operation from a 440-volt, alternating-current supply.

In operation this machine is quite similar to the type 76-A direct-current machine described in connection with Approvals 2-749 and 2-749A. It is powered by 3 motors, two 70-horsepower and one 50-horsepower. The two 70-horsepower motors furnish power for driving the breaker arms. The 50-horsepower motor furnishes power for all the other functions. All of the drives on the machine are actually carried out hydraulically by pumps and hydraulic motors.

There were eight explosion-proof electrical parts on this machine: (1) Two 70-horsepower motors; (2) a 50-horsepower motor; (3) a control box; (4) 2 lights; (5) a push-button switch box; and (6) a circuit breaker and plug box.

The wiring between the various electrical parts is protected from mechanical injury by conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power is conducted to the machine through No. 2/0, 3-conductor, type G, flame-resistant cable, 500 feet (or less) long. The cable is protected at the outby end by three 300-ampere fuses. An insulated mechanical strain clamp prevents strains on the terminal connections at the machine.

No extensions of this approval to allow changes have been granted.

Type 76-A A.-C. Colmol Mining Machine

Approval 2-985, covering the design of the type 76-A, alternating-current, Colmol mining machine, was issued to The Jeffrey Manufacturing Co. on February 26, 1954. The approval applied to machines for operation from a 220-volt, alternating-current supply. Under date of April 19, 1954 Approval 2-985A was issued for machines for operation from a 440-volt, alternating-current supply.

In operation this machine is quite similar to the type 76-A direct-current machine described in connection with Approvals 2-749 and 2-749A. It is powered by three 50-horsepower motors. Two of the motors furnish power for driving the breaker arms. The other motor furnishes power for all the other functions. All of the drives on the machine are actually carried out hydraulically by pumps and hydraulic motors.

There were eight explosion-proof electrical parts on this machine: (1) Three 50-horsepower motors; (2) a control box; (3) 2 lights; (4) a push button switch box; and (5) a headlight resistance on 220-volt or a transformer on 440-volt machines.

The wiring between the various electrical parts is protected from mechanical injury by conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power is conducted to 220-volt machines through 3 single conductor, 250,000 c.m. cables, and a No. 2/0 cable is used for the frame ground. For 440-volt machines the cable is 4-conductor, No. 2/0. These cables are 500 feet or less in length and are flame resistant. Protection at the outby end of the cables for 220-volt machines is provided by three 750-ampere fuses or by a circuit breaker set at 1,500 amperes. For 440-volt machines, three 400-ampere fuses or a circuit breaker set at 1,000 amperes is used. An insulated strain clamp prevents strains on the terminal connections for the cables at the machine.

Type MM-34F-52 Mining Machine

Approval 2-888A, covering the design of the type MM-34F-52 mining machine, was issued to The Jeffrey Manufacturing Co. on December 3, 1952. This original approval applied to machines for operation from a 500-volt, direct-current supply. Under date of December 15, 1954, Approval 2-888 was issued for machines for operation from a 250-volt, direct-current supply.

The machine consists of two separate units. Figure 6 shows the crawler-mounted unit that takes the coal from the face. Figure 7 shows the power-supply unit. The two units are electrically connected by two 9-conductor, flame-resistant cables. These cables are in 100-foot lengths equipped with plug and socket connectors and carry intrinsically safe pilot circuits so arranged that the cables can be connected and disconnected without hazard.

Figure 6. - Jeffrey type MM-34F-52 mining machine.

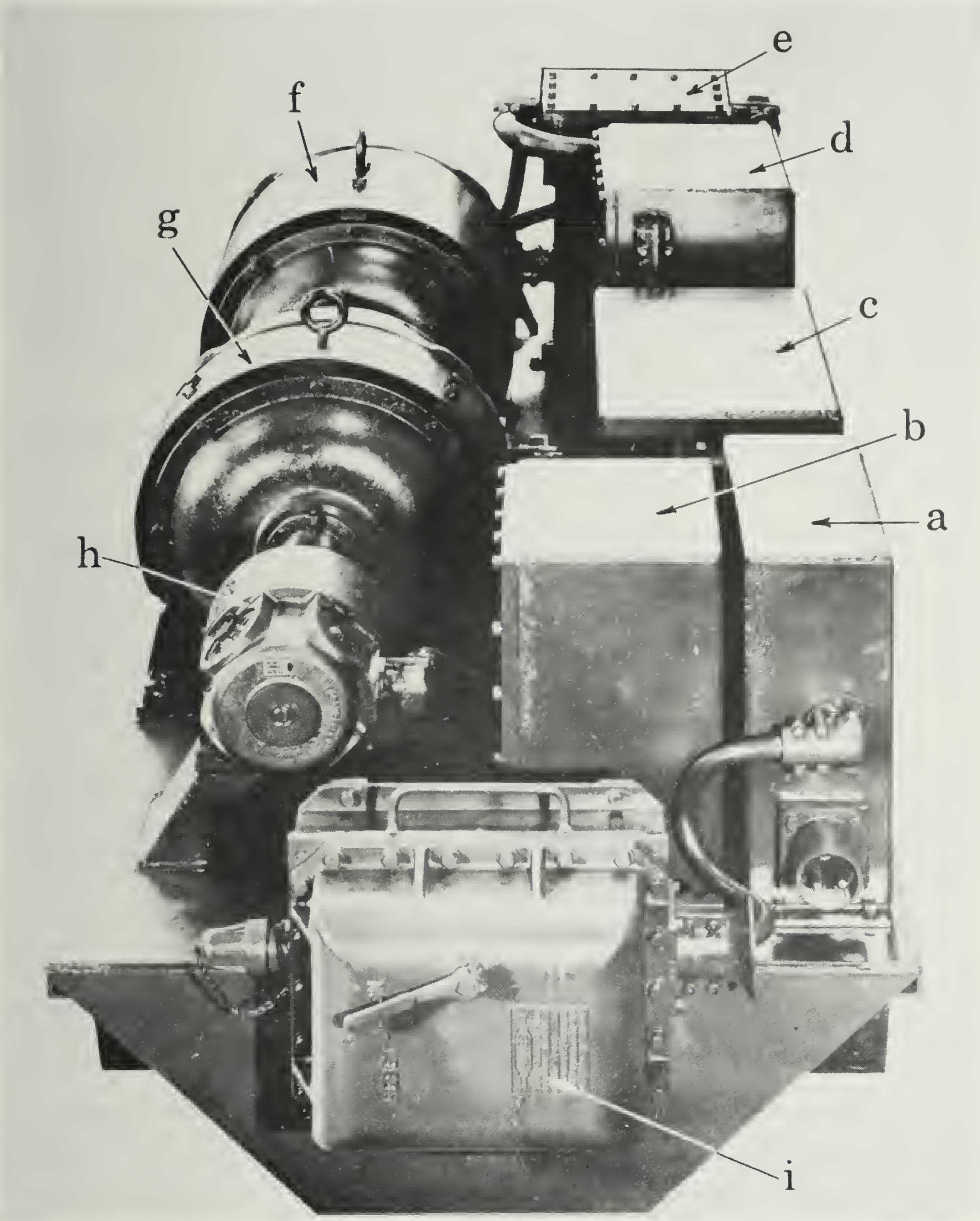

Figure 7. - Jeffrey type MM-34F-52 mining machine.

In operation, the coal is undercut and sheared by the four cutter chains, producing a hanging block of coal. The two rapidly vibrating Syntron hammers striking this block cause the coal to fall from the face. The fallen coal is swept onto the conveyor, which carries it to the rear of the machine where it is loaded onto haulage equipment.

The electrical parts on the face unit, figure 6, were: (1) A 75-horsepower motor; (2) a starting box; (3) 2 emergency switches; (4) 2 lights; and (5) 2 Syntron hammers. The power supply unit, figure 7, carried the following parts: A 15-horsepower controller at a, a resistor at b, a 75-horsepower starter at c, a Syntron hammer control at d, a rectifier at e, an alternating-current generator at f, a 15-horsepower motor at g, an exciter at h, and on the original design a power take-off at i. The alternating-current generator and rectifier supply power for the Syntron hammers. In figure 6 only the 2 Syntron hammers at a and 1 of the headlights at b can be readily seen. A start switch has been added to the parts on this unit by extension of approval.

The wiring between the various electrical parts is protected from mechanical injury by conduits and by position. Appropriate overload devices are used to protect against excessive overcurrents.

Power is conducted from the source to the power unit by 100-foot lengths of 5-conductor, flame-resistant cable. For 500 volts, the 2 power conductors and the ground conductor are each No. 1/0 size and the 2 pilot wires are No. 10 size. For 250 volts the 2 power conductors are each 4/0 size, and the ground conductor is 1/0 size. The two pilot wires are No. 10 size. The 100-foot lengths of cable are equipped with connectors, and the intrinsically safe circuit carried by the pilot wires is so arranged that the cable can be connected and disconnected without hazard.

The cable is protected at the outby end by a circuit breaker. The breaker setting is 850 amperes for 500 volts and 1,700 amperes for 250 volts. The circuit-breaker unit is also essential in connection with the intrinsically safe circuit that functions to provide for safe connections and disconnections of the cables.

APPROVED MACHINES BUILT BY THE LEE-NORSE CO.

Model CM46-1 Koal Master

Approval 2-783, covering the design of the Model CM46-1 Koal Master, was issued to the Lee-Norse Co. on April 10, 1951. The approval applies to machines for operation from a 250-volt, direct-current supply. Figure 8 shows the CM6-1 Koal Master.

This is essentially a rubber-tire-mounted machine with a mechanism mounted on its front end for removing coal from the solid face. This mechanism consists of 2 heads each carrying 5 disks on which are mounted cutting bits. These disks rotate about horizontal axes. The two heads are pivoted and move alternately toward and away from each other in a horizontal direction. In operation the heads are sumped into the coal at the top of the seam and then swing downward dislodging the coal as they move. The loose coal is fed to a conveyor at the center of the machine by the loading mechanism. The conveyor at the rear delivers the coal to haulage equipment for transportation to the surface.

There were 13 explosion-proof electrical parts on this machine: (1) Two 60-horsepower motors; (2) a 15-horsepower motor; (3) a starter for the 60-horsepower

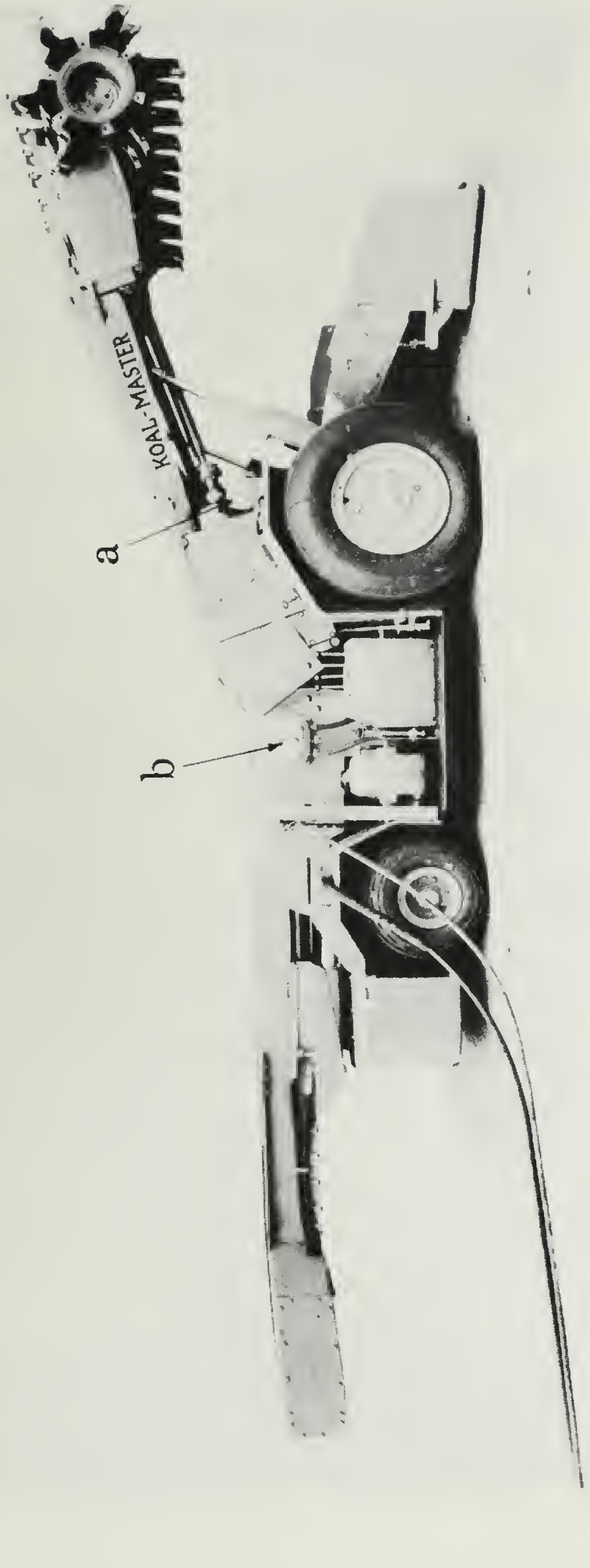

Figure 8. - Lee-Norse model CM46-1 Koal Master.

motors; (4) a starter for the 15-horsepower motor; (5) a control station; (6) 3 headlights; (7) a headlight resistance; (8) a headlight relay; (9) a control station; and (10) a circuit breaker. Some of these parts can be seen in figure 8, but many are obscured by other parts of the machine. A headlight is at a and a control station at b.

The wiring between the various electrical units is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive electrical overcurrents and short circuits.

Power is conducted to the machine through 300 feet of No. 2/0, type G, flame-resistant, portable cable. The cable is protected by a circuit breaker set at 1,000 amperes at the outby end. The cable is held by a strain clamp to prevent strains on the terminal connections at the machine.

Model CM50 Miner

Approval 2-881, covering the design of the Model CM50 miner, was issued to the Lee-Norse Co. on November 3, 1952. The approval applies to machines for operation from a 250-volt, direct-current supply.

The Model CM50 miner is a caterpillar-mounted machine. It operates in the same general manner as the Model CM46-1 machine previously described. It differs from that machine in that each of the 2 heads has only 2 revolving disks with cutter bits instead of 5.

There were 11 explosion-proof electrical parts on the Model CM50 miner: (1) Two 60-horsepower motors; (2) one 15-horsepower motor; (3) one 5-horsepower motor; (4) a controller; (5) a resistor; (6) a control station; (7) 2 headlights; (8) a headlight resistance; and (9) a circuit breaker.

The wiring between the various electrical parts is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive electrical overcurrents and short circuits.

Power is conducted to the machine through 500 feet of 2/0 type G, flame-resistant, portable cable. The cable is protected by a circuit breaker set at 1,000 amperes at the outby end. The cable is held by a strain clamp to prevent strains on the terminal connections at the machine.

Several optional parts have been allowed by extensions of the approval as follows: (1) Two 30-horsepower motors in place of the original 60-horsepower motor; (2) a 20-horsepower motor in place of the 15-horsepower motor; (3) a 6-horsepower motor in place of the 5-horsepower motor; (4) modified 60-horsepower motors in place of the original 60-horsepower motors. Also, a modified controller compartment has been included.

Model CM-32 Miner

Approval 2-954, covering the design of the Model CM-32 miner, was issued to the Lee-Norse Co. on September 14, 1953. The approval applies to machines for operation from a 250-volt, direct-current supply.

The Model CM-32 miner is mechanically similar to the Model CM-50 described in connection with Approval 2-881. The present machine, however, is for use in low seams.

There were 10 or 11 explosion-proof electrical parts on the Model CM-32 miners, depending on whether 1 or 2 headlights were used: (1) Two 20-horsepower motors; (2) two 6-horsepower motors or optional 5-horsepower motors; (3) a 10-horsepower motor; (4) 2 magnetic controllers; (5) a control station; (6) 1 or 2 headlights; and (7) a headlight resistance.

The wiring between the various electrical parts is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive electrical overcurrents and short circuits.

Power is conducted to the machine through its 500-foot length of No. 1, twin parallel, type G, flame-resistant, portable cable. The cable is protected by a circuit breaker set at 1,000 amperes at the outby end. The cable is held by a strain clamp to prevent strains on the terminal connections at the machine.

Model CM-36 Miner

Approval 2-973, covering the design of the Model CM-36 miner, was issued to the Lee-Norse Co. on December 21, 1953. The approval applies to machines for operation from a 250-volt, direct-current supply. Figure 9 shows the Model CM-36 miner.

The Model CM-36 miner is a caterpillar-mounted machine similar to the Model CM-32 of Approval 2-954 which it supersedes. Therefore it is mechanically similar to the Model CM-50 described in connection with Approval 2-881.

There were 10 or 11 explosion-proof electrical parts on this machine, depending on whether 1 or 2 headlights are used: (1) Two 40-horsepower motors; (2) a 15-horsepower motor; (3) two 10- or 8-horsepower motors; (4) 2 magnetic controllers; (5) a control station; (6) 1 or 2 headlights; and (7) a headlight resistance. Some of these parts can be seen in figure 9, but some are obscured by other parts of the machine. One of the motors driving the cutters is at a, the pump motor is at b, the conveyor motors are at c, one of the magnetic controllers is at d, and the headlight can be seen at e.

The wiring between the various electrical parts is protected by hose conduit and by position from mechanical injury. Appropriate overload devices are used to protect against excessive electrical overcurrents and short circuits.

Power is conducted to the machine through its 500-foot length of No. 1 twin-parallel, type G, flame-resistant, portable cable. The cable is protected by a circuit breaker set at 1,000 amperes at the outby end. The cable is held by a strain clamp to prevent strains on the terminal connections at the machine.

Redesigned Model CM-50 Miner

Approval 2-994, covering the design of the redesigned Model CM-50 miner, was issued to the Lee-Norse Co. on April 30, 1954. The approval applies to machines for operation from a 250-volt, direct-current supply.

This machine varies somewhat both electrically and mechanically from the original Model CM-50 miner described in connection with Approval 2-881. It is a caterpillar-mounted machine and operates in the same general manner as the Model CM46-1 machine previously described. However, each of the 2 heads has only 2 revolving disks with cutter bits instead of 5.

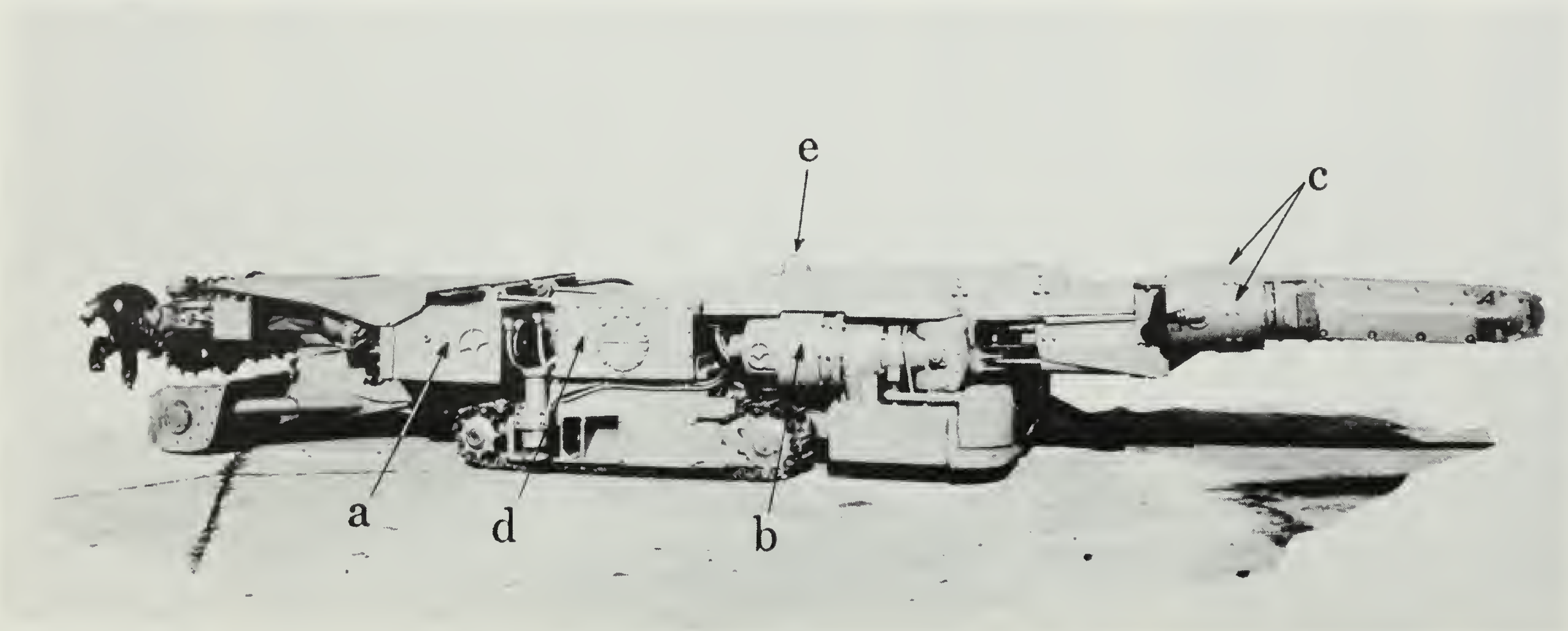

Figure 9. - Lee-Norse model CM-36 miner.

There were 11 explosion-proof electrical parts on the redesigned Model CM-50 miner: (1) Two 40-horsepower motors; (2) two 10- or 8-horsepower motors; (3) a 20-horsepower motor; (4) a controller; (5) a resistor case; (6) a control station; (7) 2 headlights; and (8) a headlight resistance. A 40-horsepower motor in place of the 20-horsepower motor has been authorized by an extension of the approval.

The wiring between the various electrical parts is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive electrical overcurrents and short circuits.

Power is conducted to the machine through 500 feet of No. 2/0, 2-conductor, type G, flame-resistant cable. The cable is protected by a circuit breaker set at 1,000 amperes at the outby end. The cable is held by a strain clamp to prevent strains on the terminal connections at the machine.

APPROVED MACHINES BUILT BY THE MARIETTA MANUFACTURING CO.

Marietta Miner, Layout Drawing 31772

Approval 2-922, covering the design of the Marietta miner (layout drawing 31772), was issued to the Marietta Manufacturing Co. on April 6, 1953. The approval applies to machines for operation from a 250-volt, direct-current supply. Figure 10 shows this Marietta miner. The cutting bits are not shown in the illustration.

The Marietta miner is a boring-type machine. The coal is dislodged from the solid coal face by 2 rotating heads, each having 2 arms holding cutting bits and producing overlapping circular kerfs. A drilling bit at the center of each head acts to break the center core. Cutter chains cut off the wedges of coal left at the top and bottom with the rotating cutter heads. The coal dislodged from the face falls down and is pushed toward the center of the machine by the rotating arms and is forced onto the chain conveyor by the forward motion of the machine as it advances on its caterpillar treads. The conveyor chain and the caterpillar treads are driven by hydraulic motors.

Power for driving the two rotating heads and for the cutter chains is supplied by one motor through a suitable shear coupling and reduction gear assemblies. All other functions of the machine are performed hydraulically. Another motor drives the hydraulic pumps.

There were 12 explosion-proof electrical parts on this machine: (1) A 70-horsepower motor driving the cutting elements; (2) a 25-horsepower motor driving the hydraulic pumps; (3) a master control; (4) a control group; (5) an emergency stop switch; (6) 4 resistance boxes; (7) 2 headlights; and (8) a tail light. Some of these can be seen in figure 10, but most of them are obscured by other parts of the machine.

The 25-horsepower motor driving the hydraulic pumps is at _a_, the control group is at _b_, 1 of the headlights is at _c_, and the tail light is at _d_.

The wiring between the various electrical units is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive electrical overcurrents and short circuits.

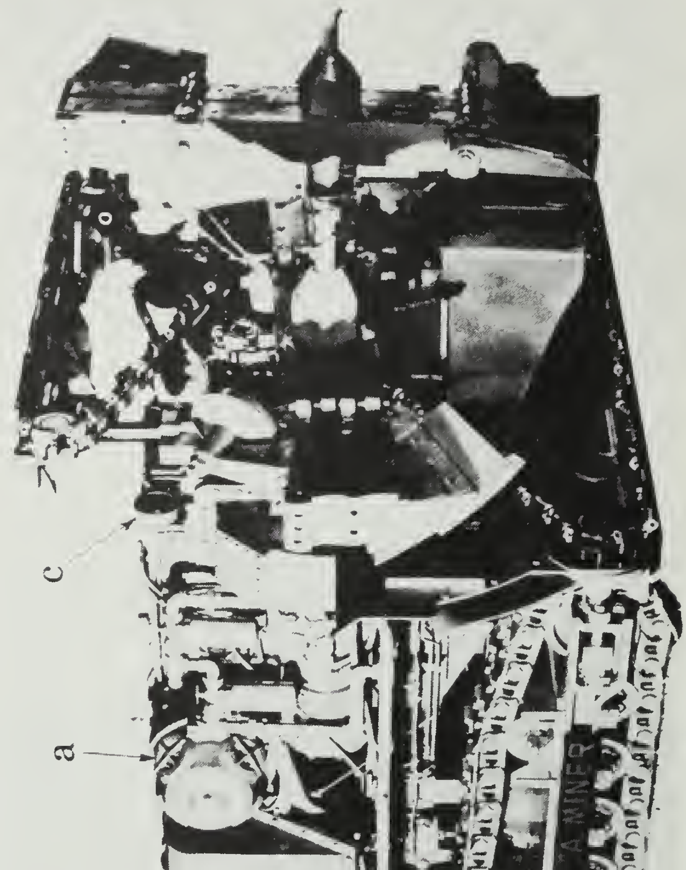

Figure 10. - Marietta miner.

Power is conducted to the machine through 2 lengths (500 feet or less) of 250,000-c.m., single-conductor, flame-resistant, portable cable. A single-conductor 2/0, flame-resistant cable is used for the frame ground. The cable is protected by a circuit breaker set to trip at 600 amperes at the outby end. An insulated mechanical strain clamp prevents strains on the terminal connections at the machine.

Marietta Miner, Layout Drawing 31787

Approval 2-957, covering the design of the Marietta miner (layout drawing 31787), was issued to the Marietta Manufacturing Co. on October 13, 1953. The approval applies to machines for operation from a 250-volt, direct-current supply.

In general, this machine is quite similar to that described in connection with Approval 2-922. Two 70-horsepower motors are used on the present machine instead of one 70- and one 25-horsepower motor as used on the machine of Approval 2-922. The second 70-horsepower motor, besides driving the hydraulic pumps, supplies its excess power to the coal-cutting gear train through a friction clutch.

There were 13 explosion-proof electrical parts on this machine: (1) Two 70-horsepower motors; (2) a controller; (3) a control group; (4) an emergency control switch; (5) 4 resistance boxes; (6) 2 headlights; (7) a tail light; and (8) a warning light.

The wiring between the various electrical units is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive electrical overcurrents and short circuits.

Power is conducted to the machine through 2 lengths (500 feet or less) of 350,000-c.m., single-conductor, flame-resistant, portable cables. A single-conductor 4/0, flame-resistant cable is used for the frame ground. The cable is protected by a circuit breaker set to trip at 800 amperes at the outby end. An insulated mechanical strain clamp prevents strains on the terminal connections at the machine.

Marietta Miner, Layout Drawing 31804

Approval 2-990, covering the design of the Marietta miner (layout drawing 31804), was issued to the Marietta Manufacturing Co. on March 17, 1954. The approval applies to machines for operation from a 250-volt, direct-current supply.

In general, this machine is quite similar to those covered by Approvals 2-922 and 2-957 as already described. One 70-horsepower motor and one 25-horsepower motor are used on the present machine.

There were 12 explosion-proof electrical parts on this machine: (1) A 70-horsepower motor; (2) a 25-horsepower motor; (3) 2 controllers; (4) a control switch; (5) 4 resistance boxes; (6) 2 headlights; and (7) a tail light.

The wiring between the various electrical units is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive electrical overcurrents and short circuits.

Power is conducted to the machine through 2 lengths (500 feet or less) of 250,000-c.m., single-conductor, flame-resistant, portable cables. A single-conductor, 2/0, flame-resistant cable is used for the frame ground. The power cables are

protected by a circuit breaker set to trip at 600 amperes at the outby end. An insulated mechanical strain clamp prevents strains on the terminal connections at the machine.

APPROVED MACHINES BUILT BY THE GOODMAN MANUFACTURING CO.

Types E-2600 and 2600 Mining and Loading Machines

Approval 2-765, covering the design of the type E-2600 mining and loading machine, was issued to the Goodman Manufacturing Co. on November 6, 1950. The approval applies to machines for operation from a 250-volt, direct-current supply. Only one of the type E-2600 machines has been built, and it has been replaced by the type 2600 mining and loading machine whose design was covered by an extension of Approval 2-765 granted March 2, 1954. Figure 11 shows the type 2600 machine. The timber-setting arms are optional.

In operation the cutting head a is sumped into the coal at the top of the face by advancing the machine on its caterpillar treads. The cutting head is then swung downward to the bottom, the moving bits dislodging the coal as the head travels downward. The loose coal is swept onto a conveyor that runs through the center of the machine by the gathering arms b. The cutting bits are carried by 2 cutter chains, 1 on each side of the head, and a revolving drum between the 2 chains. (The cutting bits are not shown in place in the tool holders on the illustration.) The cutting head can be swung horizontally through an arc on each side of the center line of the machine. Also, the rear conveyor c can be swung horizontally to either side of the center line and raised or lowered.

There were 25 explosion-proof electrical parts on this machine: (1) Two 75-horsepower motors, each driving the cutter chains; (2) two 8-horsepower motors, driving the rear conveyor; (3) an 8-horsepower motor driving a hydraulic pump; (4) two 7-1/2-horsepower motors driving the caterpillar treads for tramming; (5) 2 contactor and relay cases; (6) 10 resistance cases; (7) a tramming controller; (8) a remote-control station for the hydraulic pump; (9) a start-stop push button for the cutter-chain motors; (10) 2 headlights; and (11) a headlight switch. Some of these accessories can be readily seen in figure 11, but many of them are obscured by other parts of the machine. One of the motors driving the cutter chain is at d, one of the rear conveyor motors is at e, one of the contactor and relay cases is at f, a controller is at g, a push button is at h, and a switch is at j. The 2 headlights are plainly visible, 1 on either side near the front of the machine.

The wiring between the various electrical units is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive electrical overcurrents and short circuits.

Power is conducted to the machine through 500 feet or less of 4/0, parallel-duplex, type G, flame-resistant, portable cable. The cable is protected by a 1,200-ampere instantaneous trip circuit breaker at the outby end. A mechanical strain clamp held by the chains i prevents strains on the terminal connections at the machine.

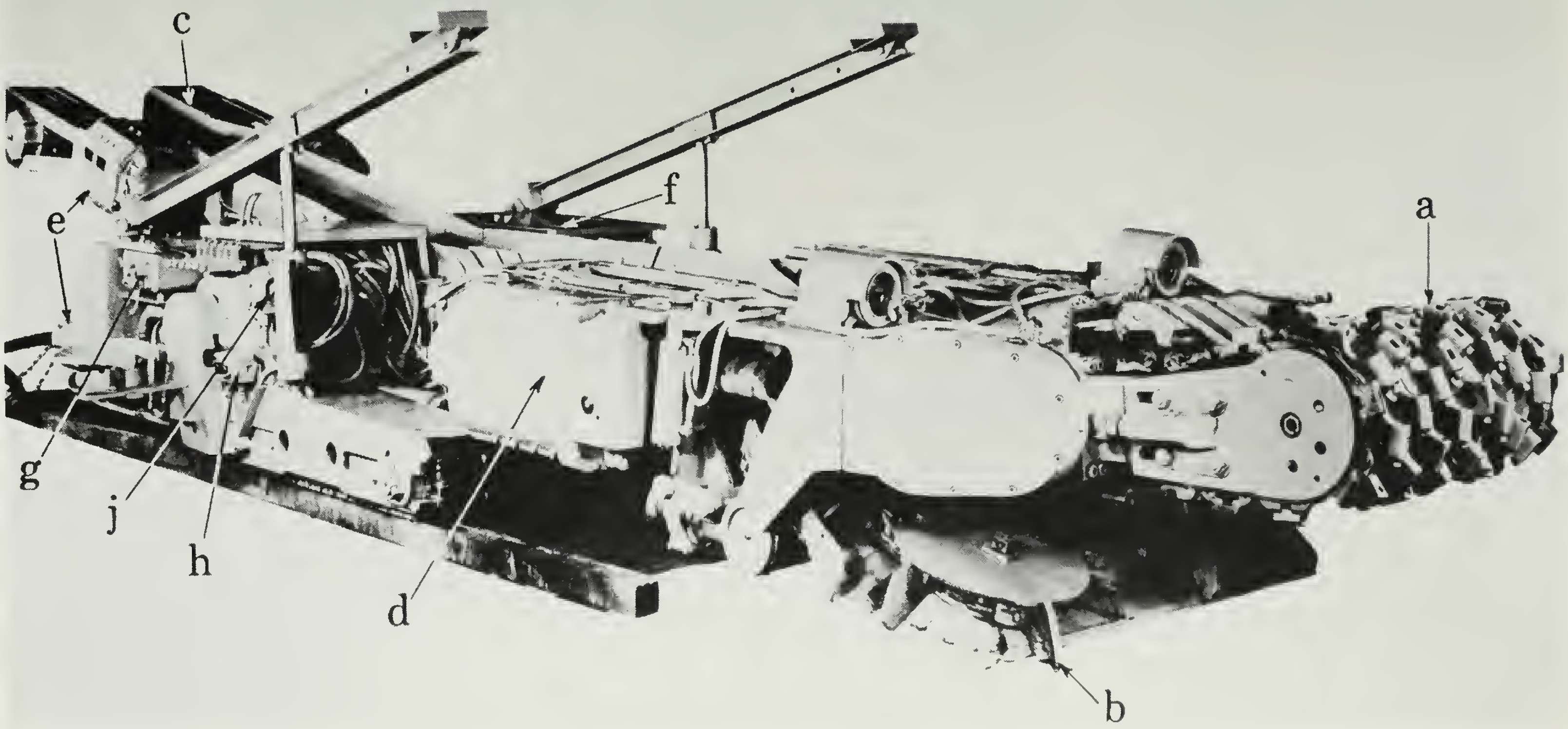

Figure 11. - Goodman type 2600 mining-loading machine.

Type 500 Miner

Approval 2-974, covering the design of the type 500 miner, was issued to the Goodman Manufacturing Co. on December 21, 1953. The approval applies to machines for operation from a 250-volt, direct-current supply. The use of an optional contactor case has been allowed by an extension of approval granted March 5, 1954. Figure 12 shows the type 500 miner.

The type 500 miner is a boring-type machine. The coal is cut from the solid face by 2 rotating heads, each having 3 arms, holding cutting bits and producing overlapping circular kerfs. A conically shaped screw is located at the center of each revolving head and acts to break the central core. A cutter chain cuts off the top and bottom wedges of coal left by the rotating cutters. The coal dislodged from the face falls down and is pushed toward the center of the machine by the rotating arms and is forced onto the chain conveyor by the forward motion of the machine as it advances on its caterpillar treads. The conveyor chain and the caterpillar treads are driven by hydraulic motors.

The rotating arms can be retracted, the top cutter chain bar can be lowered and the bottom chain cutter bar can be raised, and this whole cutting head can be lowered and also tilted to give clearance for tramming. The rear end of the conveyor has both horizontal and vertical motion. These movements are all hydraulically controlled. There were six explosion-proof electrical parts on this machine: (1) A 100-horsepower motor driving the cutting elements; (2) a 50- horsepower motor driving hydraulic pumpa; (3) a contactor case; (4) 2 headlights; and (5) a conveyor light. Some of these accessories can be seen in figure 12, but some are obscured by other parts of the machine.

The 100-horsepower, fan-cooled motor driving the cutting element is at a, the contactor case is at b, 1 of the 2 headlights is at c. The contactor case is a ventilated design to remove corrosive compounds resulting from fixation of nitrogen by the electric arcs from the contactors. The explosion-proof breather for discharging the ventilating air can be seen at d.

The wiring between the various electrical units is protected from mechanical injury by hose conduits and by position. Appropriate overload devices are used to protect against excessive electrical overcurrents and short circuits.

Power is conducted to the machine through 500 feet or less of 4/0, 3-conductor, flame-resistant, portable cable. One conductor is used for a frame ground connection. The cable is protected by an instantaneous-trip circuit breaker set at 1,500 amperes. A ground-fault current trip is incorporated in the design of the protecting device. A mechanical cable strain clamp secured to the machine by a chain prevents strains on the terminal connection at the contactor case.

APPROVED MACHINES BUILT BY THE ENSIGN ELECTRIC & MANUFACTURING CO.

Bulletin 2025 Mining Machine

Approval 2-945A, covering the design of the Bulletin 2025 mining machine, was issued to the Ensign Electric & Manufacturing Co. on July 13, 1953. The approval applies to machines for operation from a 440-volt, alternating current supply.

Figure 13 shows a general view of a machine similar to the one originally approved. In operation, a planer or plow, a, while traveling in either direction

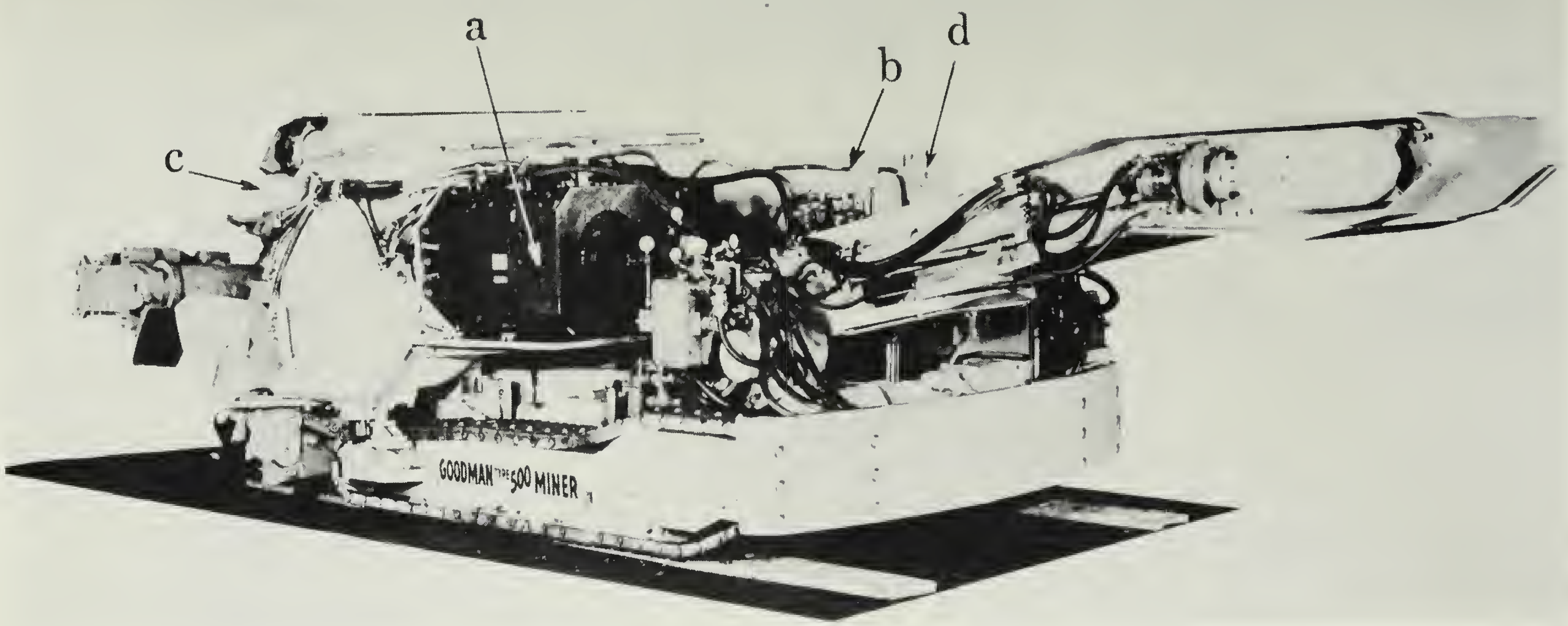

Figure 12. - Goodman type 500 miner.

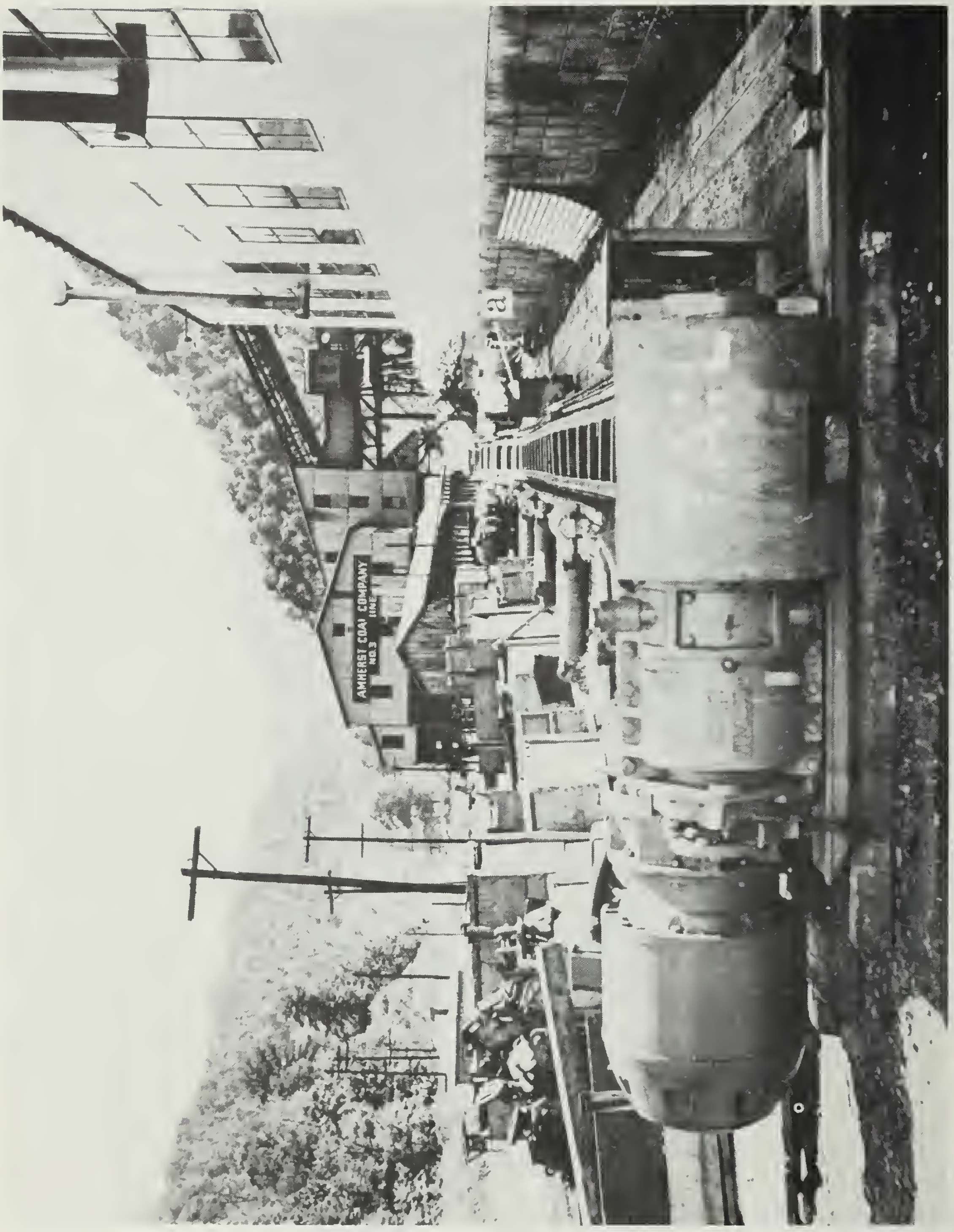

Figure 13. - Ensign bulletin 2025 mining machine.

mines coal from the solid face and plows it onto the conveyor. A detailed description of a comparable machine has been published in a Bureau of Mines publication.[2] The machine there described is of German manuracture. The electrical parts of the machine covered by the present approval are of American design and manufacture.

Thirty-seven parts in connection with this machine were required to be explosion-proof: (1) Three 50-horsepower motors; (2) 3 starters for 50-horsepower motors; (3) 2 limit switches; (4) 2 air valves; (5) 24 signal lights; (6) a master control case; (7) a 25-horsepower motor; and (8) a reversing starter. An explosion-proof meter case was added to the preceding parts by an extension of approval. Later, an auxiliary conveyor, including a 10-horsepower motor and a starter, was added by another extension of approval. Two connection boxes not required by the Bureau's schedule to be explosion-proof were explosion-proof also.

Power was conducted to the machine through 4 No. 2, 4-conductor and 1 No. 8, 4-conductor cables not over 500 feet long. Appropriate overload devices are used to protect the various circuits from excessive overcurrents. A circuit breaker, set at 150 amperes, is used at the outby end of each of the 3 large portable cables, and a circuit breaker set at 40 amperes is used at the outby end of the small portable cable.

An extension of approval was granted covering the design of a changed machine. The explosion-proof parts on this machine are the same as those listed for the original approval, except that four instead of three 50-horsepower motors and starters are used and the 25-horsepower motor and starter are eliminated.

2/ Haley, W. A., Dowd, J. J., and Turnbull, L. A., Modified Longwall Mining With a German Coal Planer (Plow) in the Pocahontas No. 4 Coal Bed, Helen, W. Va.: Bureau of Mines Rept. of Investigations 4922, 1952, 13 pp.

Bureau of Mines
Information Circular 7737

NATIONAL ANNUAL DIESEL-FUEL SURVEY, 1955

BY O. C BLADE

United States Department of the Interior — December 1955

NATIONAL ANNUAL DIESEL-FUEL SURVEY, 1955

BY O. C BLADE

* * * * * * * * * Information Circular 7737

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
Thos. H. Miller, Deputy Director

The work upon which this report is based was done under a cooperative agreement between the Bureau of Mines, United States Department of the Interior, and the American Petroleum Institute.

December 1955

FOREWORD

This and succeeding publications concerning analyses of petroleum products in commercial use (which include surveys on aviation gasoline, motor gasoline, and diesel fuel) will be issued as Information Circulars instead of Reports of Investigations as in the past. This change is being made in accordance with Bureau of Mines policy which restricts the use of Reports of Investigations to the presentation of results of original Bureau of Mines research. Previous publications dealing with diesel fuel are Reports of Investigations 4746, 4830, 4935, 5008, and 5084.

NATIONAL ANNUAL DIESEL-FUEL SURVEY, 1955

by

O. C. Blade 1/

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INTRODUCTION

Total sales of diesel fuel in the United States continue to increase. This growth is due primarily to two causes: More conversion to diesel units by the railroads in recent years, and the greater use of diesel engines in trucks, busses, and tractors. Following are some figures on the distribution of the fuel computed from data issued by the Bureau of Mines. 2/

	1953		1954	
	Thsds. bbl.	percent	Thsds. bbl.	percent
Railroads	70,669	45.6	72,907	46.2
Trucks, busses, and tractors	34,980	22.6	38,809	24.6
Vessels	21,116	13.6	19,011	12.1
Smelters, mines, and manufacturing	16,238	10.5	16,145	10.2
Military	6,942	4.5	6,141	3.9
Gas and electric power plants	4,257	2.7	3,738	2.4
Oil companies	735	.5	1,001	.6
Total	154,937		157,752	

Deliveries of diesel type fuel from refineries totaled 91,522,000 barrels during the first six months of 1955, 3/ a corresponding figure for 1954 was 91,170,000 barrels.

Information on the properties of this engine fuel is very important to the petroleum industry, engine manufacturers, and consumers. To supply such information the American Petroleum Institute and the Bureau of Mines, United States Department of the Interior, under cooperative agreement, are conducting annual surveys of diesel fuel oil produced in refineries in this country.

Samples of diesel fuel typical of their manufacture were analyzed by the refiners in accordance with instructions from the subcommittee on fuel surveys of the Automotive Research Committee of the American Petroleum Institute. Results of the analyses were transmitted to the Bureau of Mines, where the data were studied and compiled as shown in the tables of this report. Five surveys of diesel fuel made in this manner were published as Bureau of Mines reports in 1950, 1951, 1952, 1953, and 1954. 4/ This report shows the results of a survey made during 1955.

2/ Coumbe, A. T., and Avery, I. F., Sales of Fuel Oil and Kerosine in 1954: Bureau of Mines Mineral Market Report MMS 2412, 1955, 16 pp.

3/ Bureau of Mines, Crude Petroleum and Petroleum Products, Jan-June 1955: Bureau of Mines Monthly Petroleum Statements 387-392, total from table 2 in six reports.

4/ Blade, O. C., National Annual Diesel-Fuel Surveys, 1950-1954: Bureau of Mines Repts. of Investigations 4746, 1950, 25 pp.; 4830, 1951, 12 pp.; 4935, 1952, 22 pp.; 5008, 1953, 24 pp.; 5084, 1954, 24 pp. (In cooperation with the American Petroleum Institute).

SUMMARY

In this survey 312 samples of diesel fuel are represented. The fuels were manufactured by 46 petroleum refining companies in 104 refineries, large and small, throughout the country. The data are divided into 4 groups according to grade of diesel fuel, and each group is subdivided into 5 tabulations according to the geographic marketing distribution of the various fuels represented. The four groups according to ASTM grades are as follows:

(1-D) Diesel fuels of 625° F. maximum distillation end point; (2-D, first section) diesel fuels, of 675 ° F. maximum distillation temperature at 90 percent recovered, maximum kinematic viscosity at 100° F. of 5.8 centistokes (45 Saybolt Universal seconds) with maximum pour point 0° F.; (2-D, second section) diesel fuels, of same distillation and viscosity limitations, with minimum pour point 5° F.; and (4-D) diesel fuels not conforming to the ASTM distillation-temperature or viscosity limitations of grade 1-D and 2-D fuels.

The geographic areas are 5 general regions of the country containing 14 districts in which the diesel fuels are marketed. The areas are shown on the map (fig. 1).

Summaries of the results of the tests by grades and by regions, compared with data for 1954, are shown in tables 1 through 4. Average values of selected properties are shown for the fuels represented, and minimum and maximum figures are given for all the tests indicated.

EXPLANATION OF TABLES AND FIGURES

Fourteen laboratory tests, selected by the subcommittee on fuels surveys of the Automotive Research Committee of the API and made by procedures approved by the American Society for Testing Materials, 5/ were used to analyze the samples of diesel fuel in this survey.

Each item in tables 5 through 8 is a complete analysis of one sample of diesel fuel. The tables are arranged in four groups, according to the following limitations (p. 7), which are a modification of those in table 1 of the latest ASTM classifications. 6/

5/ American Society for Testing Materials, ASTM Standards, Part 5, Philadelphia, 1952, 1,350 pp.

6/ ---------, Tentative Classification of Diesel Fuel Oils (D975-53T); ASTM Standards on Petroleum Products and Lubricants, Philadelphia, 1954, pp. 444-446.

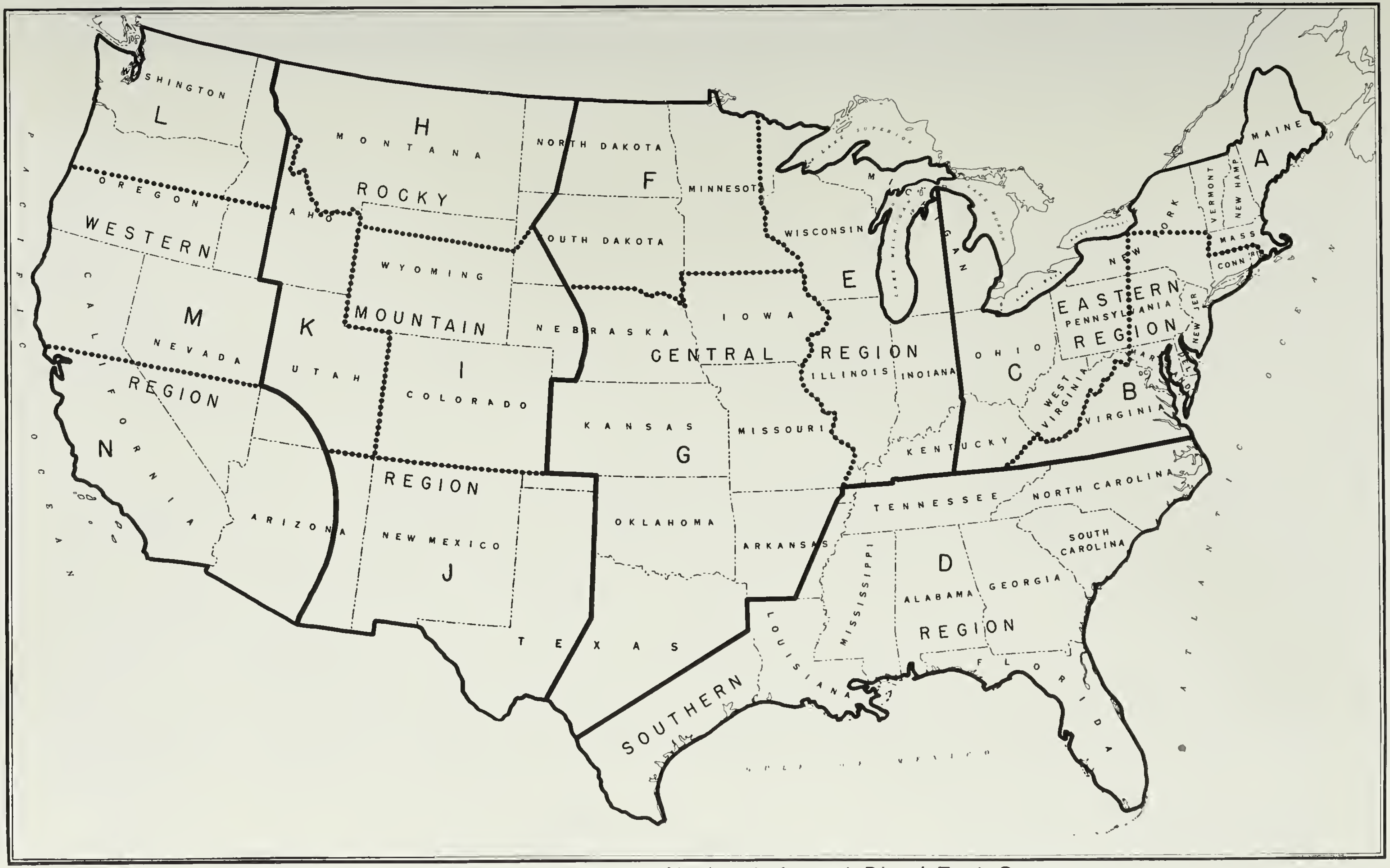

Figure I.-Geographical areas of the National Annual Diesel-Fuel Survey.

TABLE 1.--Summary of grade 1-D fuels

Diesel-fuel survey, 1955

Geographic distribution of diesel fuels 1/			Eastern region			Southern region			Central region			Rocky Mountain region			Western region		
Districts within region			A, B, C			D			E, F, G			H, I, J, K			L, M, N		
Additional districts 2/			D, E, F, G			A, B, C, E, F, G, J			A, B, C, D, H, I, J, K			D, E, F, G, L, M, N			H, K		
Number of fuels			63			24			95			41			14		
Test		A.S.T.M.	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Gravity	° A.P.I.	D287	25.7	40.9	48.4	33.3	40.5	44.6	25.7	39.9	45.7	33.0	40.5	45.1	37.4	40.9	43.8
Flash point, P.-M. closed tester	° F.	D93	114	-	220	130	-	188	125	-	220	117	-	210	132	-	170
Color:																	
A.S.T.M. Union colorimeter		D155	1	-	2½	1	-	2½	1	-	5	1	-	1½	1	-	2
Saybolt chromometer		D156	30	-	-5	30	-	1	30	-	-5	30	-	1	30	-	1
Viscosity at 100° F.:																	
Kinematic	centistokes	D445	1.40	2.02	3.17	1.49	1.96	2.79	1.49	2.18	3.34	1.47	2.15	3.34	1.47	1.96	3.02
Saybolt Universal	seconds	D88	30.4	32.7	36.6	-	32.5	35.4	-	33.3	37.1	-	33.2	37.1	-	32.5	36.1
Cloud test	° F.	D97	-60	-	12	-48	-	5	-60	-	8	-50	-	10	-56	-	0
Pour point	do	D97	-70	-	5	-55	-	0	-70	-	5	-60	-	0	-65	-	-5
Sulfur content	percent	D129	0.027	0.127	0.478	0.016	0.115	0.46	0.016	0.176	0.497	0.018	0.196	0.50	0.01	0.198	0.50
Aniline point	° F.	D611	102.0	149.4	168.8	135	147.8	164	102.0	148.8	166	117	150.1	166	134.5	149.4	161
Ramsbottom carbon residue																	
on 10 percent residuum	percent	D524	0.00	0.074	0.15	0.00	0.065	0.13	0.008	0.079	0.152	0.004	0.070	0.12	0.01	0.061	0.09
Ash content	do	D482	0.000	0.000	0.008	0.000	0.000	0.001	0.000	0.000	0.004	0.000	0.000	0.002	0.000	0.001	0.002
Cetane number		D613	42.5	51.3	60.0	45.0	50.0	58	40.6	50.9	58.5	43.8	51.1	57	46	49.5	53
Calculated cetane index		D975	43.0	50.4	59.5	43.0	48.7	54.3	40.6	49.8	58.1	44.7	50.2	57.4	41.5	49.0	54.4
Distillation test,																	
on volume recovered basis:		D86															
Initial boiling point	° F.		314	356	435	330	355	402	320	362	453	330	365	453	334	361	396
10 percent			354	401	489	355	399	450	350	407	491	350	409	491	370	403	442
50 percent			392	454	537	415	451	524	394	464	537	394	460	522	409	448	522
90 percent			453	521	591	468	517	588	457	532	592	462	524	584	465	504	584
End point			502	567	625	502	557	622	501	575	625	496	570	625	496	548	625

Diesel-fuel survey, 1954

Geographic distribution of diesel fuels 1/			Eastern region			Southern region			Central region			Rocky Mountain region			Western region		
Districts within region			A, B, C			D			E, F, G			H, I, J, K			L, M, N		
Additional districts 2/			D, E, F, G			A, B, C, E, F, G, J			A, B, C, D, H, I, J, K, L			D, E, F, G, L, M, N			F, H, I, K		
Number of fuels			57			22			82			46			19		
Test		A.S.T.M.	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Gravity	° A.P.I.	D287	29.0	41.3	48.8	34.4	41.1	44.8	33.0	40.4	46.8	23.4	40.2	44.8	23.4	39.2	44.4
Flash point, P.-M. closed tester	° F.	D93	120	-	202	130	-	180	126	-	196	122	-	182	132	-	170
Color:																	
A.S.T.M. Union colorimeter		D155	1	-	6	1	-	6	1	-	6	1	-	1½	1	-	2
Saybolt chromometer		D156	30	-	12	30	-	15	30	-	11	30	-	11	26	-	19
Viscosity at 100° F.:																	
Kinematic	centistokes	D445	1.42	2.03	3.59	1.54	1.97	3.53	1.42	2.15	3.62	1.42	2.11	3.21	1.42	2.10	3.21
Saybolt Universal	seconds	D88	-	32.7	37.9	-	32.5	37.7	-	33.2	38.0	-	33.0	36.7	-	33.0	36.7
Cloud test	° F.	D97	-50	-	10	-50	-	8	-72	-	12	-72	-	5	-62	-	0
Pour point	do	D97	-65	-	0	-65	-	5	-60	-	0	< -50	-	0	-65	-	< 0
Sulfur content	percent	D129	0.019	0.128	0.48	0.019	0.097	0.46	0.013	0.150	0.472	0.012	0.153	0.472	0.01	0.185	0.46
Aniline point	° F.	D611	126.0	150.8	165	136	149.6	167	124	150.7	171	76	147.2	164	76	140.0	161
Ramsbottom carbon residue																	
on 10 percent residuum	percent	D524	0.00	0.061	0.15	0.00	0.073	0.15	0.00	0.060	0.13	0.00	0.062	0.14	0.02	0.077	0.14
Ash content	do	D482	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.005	0.000	0.000	0.005	0.000	0.000	Trace
Cetane number		D613	43	52.1	67.8	43	51.4	60	40.4	51.1	59	43.0	50.3	58.3	44	48.4	52.0
Distillation test,																	
on volume recovered basis:		D86															
Initial boiling point	° F.		322	358	444	330	358	416	325	359	432	327	361	414	327	360	414
10 percent			361	401	500	367	399	488	358	406	496	358	406	492	373	409	492
50 percent			402	454	541	416	450	536	400	462	531	400	457	518	412	456	518
90 percent			460	518	590	462	512	586	436	528	590	436	522	590	464	514	590
End point			497	563	625	490	551	624	484	571	624	484	567	624	505	558	624

1/ Regions and districts are shown on map (fig. 1).
2/ Some of the fuels are sold in districts of more than one region.

Note: Corrosion test results, by A. S. T. M. D130, are not summarized but may be inspected in table 5.

TABLE 2.--Summary of grade 2-D fuels with maximum pour point 0° F.

Diesel-fuel survey, 1955

Geographic distribution of diesel fuels 1/			Eastern region			Southern region			Central region			Rocky Mountain region			Western region		
Districts within region			A, B, C			D			E, F, G			H, I, J, K			L, M, N		
Additional districts 2/			D, E, F, G			A, B, C, E, F, G, J			A, B, C, D, H, I, J, K			D, E, F, G, L, M			H, I, K		
Number of fuels			50			29			43			19			18		
Test		A.S.T.M.	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Gravity	° A.P.I.	D287	17.6	36.3	44.8	17.6	35.3	39.7	17.6	36.1	40.6	22.9	35.8	38.8	22.9	33.7	38.8
Flash point, P.-M. closed tester	° F.	D93	126	-	240	140	-	240	146	-	240	150	-	198	154	-	210
Color, A.S.T.M. Union colorimeter		D155	1	-	4½	1	-	4½	1	-	4½	1	-	3½	1	-	4½
Viscosity at 100° F.:																	
Kinematic	centistokes	D445	2.09	2.74	4.39	2.30	2.93	4.39	2.10	2.95	5.51	2.13	2.86	3.30	2.13	3.10	3.95
Saybolt Universal	seconds	D88	33.0	35.2	40.4	33.7	35.8	40.4	33.0	35.9	44	33.1	35.6	37.0	33.1	36.4	39.0
Cloud test	° F.	D97	-12	-	22	-5	-	14	-50	-	16	-22	-	14	-22	-	10
Pour point	do	D97	-40	-	0	-15	-	0	-85	-	0	-30	-	0	-30	-	0
Sulfur content	percent	D129	0.03	0.275	0.70	0.05	0.297	0.78	0.059	0.293	0.78	0.12	0.467	0.97	0.28	0.533	0.97
Aniline point	° F.	D611	62.0	147.6	175.6	62.0	146.4	169	62.0	150.2	169.5	70	144.9	162.5	70	138.8	149.0
Ramsbottom carbon residue																	
on 10 percent residuum	percent	D524	0.01	0.113	0.34	0.01	0.109	0.29	0.04	0.110	0.29	0.002	0.092	0.20	0.06	0.105	0.20
Ash content	do	D482	0.000	0.001	0.006	0.000	0.001	0.006	0.000	0.001	0.005	0.000	0.002	0.006	0.000	0.001	0.006
Cetane number		D613	43	50.5	60	45.0	50.3	58	40	50.9	58	45	49.8	54.6	41	45.4	51.4
Calculated cetane index		D975	41.0	50.4	64.2	42.5	49.5	56.5	40.2	51.5	59.4	42.0	49.5	55.2	41.0	46.2	51.0
Distillation test,																	
on volume recovered basis:		D158															
Initial boiling point	° F.		318	367	472	327	376	472	330	372	472	346	384	427	350	379	427
10 percent			372	432	506	410	439	506	389	438	506	398	438	472	409	444	470
50 percent			461	507	552	468	512	580	482	514	580	471	502	530	471	511	542
90 percent			556	590	648	569	592	648	565	596	648	529	586	623	529	597	626
End point			626	646	700	627	650	700	626	652	770	626	648	704	630	663	704

Diesel-fuel survey, 1954

Geographic distribution of diesel fuels 1/			Eastern region			Southern region			Central region			Rocky Mountain region			Western region		
Districts within region			A, B, C			D			E, F, G			H, I, J, K			L, M, N		
Additional districts 2/			D, E, F, G			A, B, C, E, F, G, J			A, B, C, D, H, I, J, K			D, E, F, G, L, M, N			H, I, K		
Number of fuels			53			33			59			32			17		
Test		A.S.T.M.	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Gravity	° A.P.I.	D287	29.5	36.3	44.4	28.4	35.5	39.0	28.3	36.4	40.1	29.5	36.4	40.0	27.4	33.9	39.1
Flash point, P.-M. closed tester	° F.	D93	140	-	235	140	-	230	150	-	235	152	-	210	152	-	204
Color, A.S.T.M. Union colorimeter		D155	1	-	6	1	-	6	1	-	6	1	-	6	1	-	4½
Viscosity at 100° F.:																	
Kinematic	centistokes	D445	2.30	2.85	4.28	2.30	3.08	5.51	2.14	3.05	5.8	2.11	3.02	3.92	2.11	3.27	3.92
Saybolt Universal	seconds	D88	33.7	35.6	40.0	33.7	36.3	44	33.1	36.2	45	33.0	36.1	38.9	33.0	36.9	38.9
Cloud test	° F.	D97	-6	-	20	-55	-	12	-50	-	30	-24	-	30	-24	-	10
Pour point	do	D97	-15	-	0	-90	-	0	-90	-	0	-30	-	0	<-35	-	0
Sulfur content	percent	D129	0.020	0.247	0.79	0.020	0.309	0.83	0.020	0.315	1.0	0.10	0.394	1.0	0.32	0.525	0.988
Aniline point	° F.	D611	122.6	150.6	171.6	131.5	150.2	169	122.6	152.4	169	132	152.8	169	101	143.7	156
Ramsbottom carbon residue																	
on 10 percent residuum	percent	D524	0.01	0.116	0.33	0.02	0.120	0.33	0.02	0.102	0.33	0.01	0.078	0.12	0.04	0.095	0.24
Ash content	do	D482	0.000	0.000	0.003	0.000	0.000	<0.01	0.000	0.000	0.004	0.000	0.001	0.004	0.000	0.001	0.004
Cetane number		D613	42.0	51.1	62.6	41	50.7	64	41	50.8	58.2	41.0	50.3	59	41.0	45.5	53.6
Distillation test,																	
on volume recovered basis:		D158															
Initial boiling point	° F.		327	374	465	330	375	466	327	385	465	338	385	456	346	383	428
10 percent			386	441	498	410	443	500	393	443	499	398	441	494	398	446	485
50 percent			476	512	544	482	517	586	480	513	586	465	510	542	465	513	538
90 percent			567	592	640	570	595	654	560	595	654	560	593	640	561	601	640
End point			626	645	702	626	650	710	626	651	712	626	648	701	626	662	701

1/ Regions and districts are shown on map (fig. 1).
2/ Some of the fuels are sold in districts of more than one region.

Note: Corrosion test results, by A. S. T. M. D130, are not summarized but may be inspected in table 6.

TABLE 3.--Summary of grade 2-D fuels with minimum pour point 5° F.

Diesel-fuel survey, 1955

Geographic distribution of diesel fuels 1/			Eastern region			Southern region			Central region			Rocky Mountain region			Western region		
Districts within region			A, B, C			D			E, F, G			H, I, J, K			L, M, N		
Additional districts 2/			E			E, G			D, I, J			G, L, M, N			K		
Number of fuels			5			3			4			9			11		
Test		A.S.T.M.	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Gravity	° A.P.I.	D287	28.2	34.4	42.6	30.9	35.0	37.3	28.2	35.6	40.1	30.6	34.0	40.1	32.0	32.8	34.6
Flash point, P.-M closed tester	° F.	D93	170	-	210	186	-	190	188	-	210	184	-	218	170	-	230
Color, A.S.T.M. Union colorimeter		D155	1	-	4½	1	-	-	1	-	4½	1	-	2	1	-	3½
Viscosity at 100° F.:																	
Kinematic	centistokes	D445	2.80	3.04	3.57	3.29	3.72	4.58	2.77	3.23	3.57	2.77	3.59	4.05	3.36	3.77	4.3
Saybolt Universal	seconds	D88	35.4	36.2	37.8	37.0	38.3	41.0	35.3	36.8	37.8	35.3	37.9	39.3	37.2	38.5	40.0
Cloud test	° F.	D97	12	-	26	5	-	-	5	-	26	5	-	40	5	-	18
Pour point	do	D97	5	-	20	5	-	15	5	-	15	5	-	15	5	-	15
Sulfur content	percent	D129	0.10	0.156	0.31	0.05	0.102	0.16	0.05	0.144	0.31	0.120	0.519	0.850	0.33	0.575	0.91
Aniline point	° F.	D611	126.8	149.1	177.8	152.8	160.9	165	126.8	155.7	166	136.2	153.2	167	141	148.9	155
Ramsbottom carbon residue																	
on 10 percent residuum	percent	D524	0.11	0.188	0.32	0.054	0.077	0.10	0.054	0.139	0.32	0.035	0.082	0.13	0.08	0.101	0.15
Ash content	do	D482	<0.001	0.001	0.001	0.000	0.000	-	0.000	0.000	0.001	0.000	0.000	0.002	0.000	0.001	0.004
Cetane number		D613	43.0	49.0	56	44	53.0	60.0	55	57.5	60.0	42	48.3	55.4	42.0	46.1	51.5
Calculated cetane index		D975	41.6	50.2	62.9	46.0	52.1	56.7	53.6	55.5	56.7	43.2	50.0	56.3	43.5	47.6	50.8
Distillation test,																	
on volume recovered basis:		D158															
Initial boiling point	° F.		362	401	444	334	373	395	389	413	434	388	418	457	380	406	434
10 percent			420	459	488	450	470	485	458	476	488	458	487	503	447	477	500
50 percent			506	523	553	524	540	558	498	528	553	498	541	558	519	542	560
90 percent			583	608	650	578	614	670	520	579	622	520	607	653	587	620	644
End point			638	658	706	632	695	808	631	640	652	631	670	720	631	682	720

Diesel-fuel survey, 1954

Geographic distribution of diesel fuels 1/			Eastern region			Southern region			Central region			Rocky Mountain region			Western region		
Districts within region			A, B, C			D			E, F, G			H, I, J, K			L, M, N		
Additional districts 2/			D, E			B, E, G			B, D, I, J			G, L, M, N			K		
Number of fuels			4			3			6			7			9		
Test		A.S.T.M.	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Gravity	° A.P.I.	D287	32.6	36.8	41.0	34.7	37.0	37.5	29.0	35.9	40.4	32.5	35.3	40.4	30.8	32.6	36.3
Flash point, P.-M. closed tester	° F.	D93	142	-	188	170	-	188	166	-	188	170	-	200	170	-	198
Color, A.S.T.M. Union colorimeter		D155	1	-	1½	1	-	-	1	-	2½	1	-	3½	1	-	5
Viscosity at 100° F.:																	
Kinematic	centistokes	D445	3.00	3.22	3.62	3.4	3.52	3.62	2.72	3.59	4.33	2.72	3.74	4.33	3.40	3.81	4.3
Saybolt Universal	seconds	D88	36.0	36.7	38.0	37.3	37.7	38.0	35.1	37.9	40.2	35.1	38.4	40.2	37.3	38.6	39.6
Cloud test	° F.	D97	6	-	10	10	-	18	10	-	30	10	-	30	0	-	10
Pour point	do	D97	5	-	-	5	-	15	5	-	15	5	-	20	5	-	20
Sulfur content	percent	D129	0.10	0.198	0.39	0.10	0.277	0.63	0.10	0.233	0.63	0.26	0.361	0.49	0.30	0.473	0.78
Aniline point	° F.	D611	134	156.1	168.8	156	160.9	164.6	126	156.6	166	149.4	157.2	166	139	143.5	150
Ramsbottom carbon residue																	
on 10 percent residuum	percent	D524	0.01	0.113	0.26	0.10	0.112	0.12	0.06	0.131	0.31	0.06	0.072	0.08	0.08	0.118	0.20
Ash content	do	D482	0.00	0.000	0.001	0.000	0.002	0.005	0.000	0.001	0.005	0.000	0.000	Trace	0.000	0.000	Trace
Cetane number		D613	43.5	52.9	57.5	53.6	56.9	59.0	53.6	57.4	59.0	44	51.7	58.2	42.0	45.3	51.0
Distillation test,																	
on volume recovered basis:		D158															
Initial boiling point	° F.		310	351	394	378	384	394	378	390	409	386	409	432	366	392	422
10 percent			408	437	470	470	480	492	449	476	503	449	470	483	444	465	483
50 percent			493	517	529	529	539	544	501	536	552	501	537	552	514	538	550
90 percent			589	603	624	589	595	603	586	600	626	586	617	634	610	625	654
End point			640	661	684	632	650	668	629	649	677	629	672	699	656	683	722

1/ Regions and districts are shown on map (fig. 1).
2/ Some of the fuels are sold in districts of more than one region.

Note: Corrosion test results, by A. S. T. M. D130, are not summarized but may be inspected in table 7.

TABLE 4.--Summary of grade 4-D fuels

Diesel-fuel survey, 1955

Geographic distribution of diesel fuels 1/			Eastern region			Southern region			Central region	Rocky Mountain region			Western region		
Districts within region				B, C			D		E					N	
Additional districts 2/				E			-		C	(No analyses of grade 4-D fuels)				-	
Number of fuels				6			5		1					3	
Test		A.S.T.M.	Minimum	Average	Maximum	Minimum	Average	Maximum	(Data on 1 sample)	-	-	-	Minimum	Average	Maximum
Gravity	° A.P.I.	D287	22.6	27.3	33.3	26.5	29.1	31.8	24.2	-	-	-	17.4	20.6	27.1
Flash point, P.-M closed tester	° F.	D93	160	-	230	178	-	255	180	-	-	-	174	-	194
Color, A.S.T.M. Union colorimeter		D155	-	-	-	-	-	-	(Black)	-	-	-	-	-	-
Viscosity at 100° F.:															
Kinematic	centistokes	D445	7.09	15.94	35.3	5.83	11.77	34.0	18.72	-	-	-	7.37	42.7	63.8
Saybolt Universal	seconds	D88	49.1	81.1	165.1	45.0	65.2	159.0	92.4	-	-	-	50.0	198.5	295.8
Cloud test	° F.	D97	24	-	34	-	-	-	-	-	-	-	-	-	-
Pour point	do	D97	-15	-	35	-5	-	45	15	-	-	-	-35	-	10
Sulfur content	percent	D129	0.30	0.577	1.09	0.17	0.416	.74	0.820	-	-	-	0.97	1.31	1.79
Aniline point	° F.	D611	117.2	163.0	182.9	153	158.9	164.5	-	-	-	-	118	128.7	145
Ramsbottom carbon residue:		D524													
on 10 percent residuum	percent		0.24	0.77	1.80	-	3/ 0.12	-	-	-	-	-	-	-	-
on 100 percent sample	do		.10	1.48	3.72	0.01	0.72	1.66	3.72	-	-	-	1.06	4.12	6.1
Ash content	do	D482	0.000	0.015	0.082	0.000	0.003	0.005	0.082	-	-	-	0.005	0.018	0.03
Cetane number		D613	34	(4)	38.0	40.0	42.3	45	-	-	-	-	-	3/ 39.5	-
Calculated cetane index		D975	53.8	58.3	60.6	44.6	49.4	54.3	-	-	-	-	-	3/ 38.0	-
Distillation test,															
on volume recovered basis:		D158													
Initial boiling point	° F.		351	398	457	358	402	438	-	-	-	-	366	383	400
10 percent			447	500	549	460	499	538	-	-	-	-	458	464	472
50 percent			534	622	695	570	625	694	-	-	-	-	555	605	658
90 percent			716	728	748	690	(4)	706	-	-	-	-	-	3/ 730	-
End point			718	773	842	-	3/ >760	-	-	-	-	-	-	3/ >760	-

Diesel-fuel survey, 1954

Geographic distribution of diesel fuels 1/			Eastern region			Southern region			Central region			Rocky Mountain region	Western region		
Districts within region				B, C			D			E, G		1		N	
Additional districts 2/				E			-			C, 1		G		-	
Number of fuels				3			5			2		1		2	
Test		A.S.T.M.	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	(4)	Maximum	(Data on 1 sample)	Minimum	(4)	Maximum
Gravity	° A.P.I.	D287	21.5	25.2	29.8	27.0	29.8	33.0	24.2	-	34.9	34.9	26.8	-	27.4
Flash point, P.-M. closed tester	° F.	D93	180	-	196	175	-	230	180	-	180	180	172	-	196
Color, A.S.T.M. Union Colorimeter		D155	-	-	-	-	-	-	2½	-	(Black)	2½	-	-	(Black)
Viscosity at 100° F.:															
Kinematic	centistokes	D445	5.8	10.1	18.72	5.80	6.13	6.76	-	-	18.72	5.36	8.6	-	8.85
Saybolt Universal	seconds	D88	45	59.3	92.4	44.9	46.0	48	-	-	92.4	43.5	54	-	55
Cloud test	° F.	D97	-	-	-	-	-	-	57	-	25	57	-	-	-
Pour point	do	D97	-20	-	25	-15	-	20	-	-	40	40	<-30	-	0
Sulfur content	percent	D129	0.28	0.760	1.18	0.20	0.43	0.76	0.27	-	0.820	0.27	1.20	-	1.30
Aniline point	° F.	D611	-	3/ 13.6	-	139.4	157.1	166	-	3/ 172	-	172	138	-	147
Ramsbottom carbon residue:		D524													
on 10 percent residuum	percent		-	-	-	0.12	-	2.84	0.08	-	-	0.08	-	-	-
on 100 percent sample	do		0.07	1.52	3.72	0.01	0.55	0.83	-	-	3.72	-	1.14	-	1.64
Ash content	do	D482	0.000	0.041	0.082	0.000	0.000	Trace	0.000	-	0.082	0.000	0.005	-	0.02
Cetane number		D613	39.9	41.5	43	36.5	42.2	49.2	-	3/ 61.8	-	61.8	39.8	-	40.0
Distillation test,															
on volume recovered basis:		D158													
Initial boiling point	° F.		-	3/ 375	-	365	381	410	-	3/ 418	-	418	370	-	384
10 percent			-	470	-	425	458	500	-	499	-	499	465	-	-
50 percent			-	560	-	525	570	610	-	608	-	608	574	-	590
90 percent			-	735	-	685	706	742	-	715	-	715	-	-	735
End point			-	860	-	760	780	800	-	768	-	768	-	-	-

1/ Regions and districts are shown on map (fig. 1).
2/ Some of the fuels are sold in districts of more than one region.
3/ Result of test on one sample only.
4/ No averages were determined as only two samples are represented.

Note: Corrosion test results, by A. S. T. M. D130, are not summarized but may be inspected in table 8.

ASTM grade	Table	Distillation temperature, ° F.	Kinematic viscosity at 100° F. centistokes
		Maximum	
1-D	5	End point, 625	---
2-D 1/	6	90% point, 675	Maximum 5.8
2-D 2/	7	90% point, 675	do. 5.8
4-D	8	---	Minimum 5.8

1/ Maximum pour point 0° F.
2/ Minimum pour point 5° F.

Each group of data is subdivided into five tabulations according to the geographic marketing distribution of the fuels represented. The geographic areas are made up of 5 general regions divided into 14 marketing districts as follows:

Region	Districts
Eastern	A, B, C
Southern	D
Central	E, F, G
Rocky Mountain	H, I, J, K
Western	L, M, N

The regions and districts are indicated in figure 1. These areas were established by a study committee of the API and are based on fuel-distribution systems, refinery locations, centers of population, temperature zones, and arteries of commerce, such as navigable waters. The districts differ from those of the 1950 diesel-fuel survey, which were the same as those used for the motor-gasoline surveys. 7/

The data in tables 5 through 8 are arranged, within each grade group, according to the regions where the fuels are sold. In each regional tabulation the districts where each fuel is sold are given in the fourth column. The listing of the

7/ Blade, O. C., National Motor-Gasoline Survey, Winter 1954-55: Bureau of Mines Rept. of Investigations 5146, 1955, 24 pp. (In cooperation with the American Petroleum Institute).

districts indicates in decreasing order the relative volume of sales for each fuel. Thus, the first district listed is that in which the greatest volume of a fuel is sold, and the analysis of this fuel is tabulated in the first section of data under the region containing that district. The second section of data, separated by a line from the first section, contains analyses of fuels that are sold in greatest volume in districts of other regions. The first section of data in each regional tabulation might be considered to represent fuels of major distribution and the second section to represent fuels of minor distribution for that particular region. It is possible that the sales volume of a given fuel may be highest in a district of one region but that the total sales in districts of another region may be greater. Consider, for example, a fuel distributed in districts C, E, and F. The greatest sales volume might be in district C of the Eastern region, but the combined sales in districts E and F of the Central region could be higher. This fuel would be listed as a fuel of major distribution in the Eastern region and as a fuel of minor distribution in the Central region. It is believed, however, that in most cases the region of greatest sales volume will contain the district of greatest sales volume.

The first column of these tables shows item numbers of the analyses, each of which represents one sample of diesel fuel. The same item number in different tables indicates that this fuel is sold in more than one region, and the analytical data are repeated.

The second column indicates the class or classes of service for which the fuels are recommended by the manufacturers as follows:

Class 1. Diesel fuel oils for city-bus and similar operation
Class 2. Fuels for diesel engines in trucks, tractors, and similar service
Class 3. Fuel for railroad diesel engines
Class 4. Heavy-distillate and residual fuels for large stationary and marine diesel engines

Analyses by class or service have not been tabulated in this survey.

In some instances a fuel has been designated for use during the summer or winter season only. The letter (S) or (W) in parenthesis following the class designation indicates the summer or winter season, respectively. Some of the contributing companies indicated that their diesel fuels also are frequently sold as burner-fuel oils. The ASTM grade numbers of these burner-fuel oils are listed in the third column of the tables.

The column headings for the data show the primary ASTM designations of the test procedures. If a test was made by another procedure, the exception is

indicated with a footnote. Colors of 1-D fuels were determined by the Saybolt chromometer nearly as often as with a Union colorimeter. Therefore, a column has been added in table 5 to indicate Saybolt color. Viscosities of some samples were determined both in centistokes and in Saybolt Universal seconds. For the majority of the samples, however, the results were determined by one method. Conversions were made to the kinematic value for all the Saybolt figures given, and to Saybolt seconds for all kinematic values of 1.83 centistokes and over. The equivalent values were secured from the amplified ASTM conversion tables 8/ and, for several Saybolt figures below 32.0 seconds, from a correlation derived from determinations reported by both methods in the diesel-fuel surveys.

Occasionally a certain property of a fuel, other than distillation temperature or viscosity, is not within the limits of the classification of its grade. That figure is noted as not included in the average. Most such exceptions are sulfur content, carbon residue, cetane number, and calculated cetane index for all grades, and, in several cases for grade 4-D, viscosity. Cetane numbers are given as reported. Some of these values were determined to the nearest whole unit and therefore have no decimal. Figures for calculated cetane index are listed in a separate column in this report. These values are based on correlations of API gravities and mid-boiling points of numerous diesel fuels with their cetane numbers and were secured from a nomograph. 9/ Distillation data are shown by ASTM Method D86 for the 1-D diesel fuels and by ASTM D158 for the heavier grade fuels.

Average values of nine selected characteristics of all the diesel fuels indicated in each of tables 5 through 8 have been computed where possible and are shown at the ends of the respective tables. Averages are not given for flash point, color, cloud test, pour point, and corrosion. Minima and maxima are shown for all the properties except corrosion.

Summaries of the results of this survey are shown with similar summaries of the results of the survey for the preceding year in tables 1, 2, 3, and 4.

Results of some studies of frequencies of certain properties of diesel fuel, from data in the diesel-fuel surveys of 1951, 1952, 1953, 1954, and 1955, are

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8/ American Society for Testing Materials, ASTM Viscosity Tables for Kinematic Viscosity Conversions and Viscosity Index Calculations: ASTM Special Technical Publication No. 43A, Philadelphia, July 1953, 56 pp.

9/ ---------, Tentative Classification of Diesel Fuel Oils (D975-53T), Appendix 2, Calculated Cetane Index: ASTM Standards on Petroleum Products and Lubricants, Philadelphia, 1954, pp. 447-449.

shown as bar charts in figures 2, 3, 4 and 5. Increments of figures for six selected properties of grades 1-D and 2-D fuels are plotted against the respective numbers of samples in terms of percent. All the samples in the five-year period are reckoned on the present basis of grade. The following excerpt from the tabulation for the present study indicates to some extent the increments used to secure frequency data.

Grade 1-D diesel fuels

	Samples represented, percent				
Viscosity, centistokes at 100° F.					
Increment	1951	1952	1953	1954	1955
-	-	-	-	-	-
2.27 - 2.51	13.2	13.2	11.0	16.0	16.4
2.52 - 2.76	14.0	11.9	11.7	11.8	11.9
-	-	-	-	-	-
Sulfur, percent by weight					
-	-	-	-	-	-
0.045 - 0.144	47.1	47.0	44.8	47.4	57.2
.145 - .244	17.6	19.0	24.8	21.0	13.9
-	-	-	-	-	-
Cetane number					
-	-	-	-	-	-
47.5 - 49.4	11.8	12.2	14.3	10.5	9.7
49.5 - 51.4	26.5	23.8	19.8	24.3	23.1
-	-	-	-	-	-
10-percent point, ° F.					
-	-	-	-	-	-
401 - 425	17.6	17.7	21.7	24.3	20.8
426 - 450	16.9	21.1	22.4	18.5	22.6
-	-	-	-	-	-
90-percent point, ° F.					
-	-	-	-	-	-
476 - 500	23.5	21.7	23.1	25.0	27.4
501 - 525	12.5	13.6	11.0	13.8	11.3
-	-	-	-	-	-
End point, ° F.					
-	-	-	-	-	-
526 - 550	16.2	12.9	15.6	17.1	21.4
551 - 575	9.6	9.5	8.2	11.8	9.5
-	-	-	-	-	-

Grade 2-D diesel fuels

Samples represented, percent

Viscosity, centistokes at 100° F.					
Increment	1951	1952	1953	1954	1955
-	-	-	-	-	-
2.77 - 3.01	23.6	22.0	22.8	23.6	16.2
3.02 - 3.26	11.4	11.8	10.6	8.3	11.5
-	-	-	-	-	-
Sulfur, percent by weight					
-	-	-	-	-	-
0.145 - 0.244	18.2	20.4	24.9	22.1	22.5
.245 - .344	20.9	18.9	14.0	8.3	14.0
-	-	-	-	-	-
Cetane number					
-	-	-	-	-	-
49.5 - 51.4	16.2	16.5	13.0	12.3	19.3
51.5 - 53.4	19.6	13.3	13.0	16.4	12.8
-	-	-	-	-	-
10-percent point, ° F.					
-	-	-	-	-	-
426 - 450	47.7	40.8	48.8	48.6	41.5
451 - 475	24.5	30.4	20.3	15.1	16.9
-	-	-	-	-	-
90-percent point, ° F.					
-	-	-	-	-	-
576 - 600	42.8	56.4	53.7	50.0	51.5
601 - 625	33.3	26.2	26.8	26.7	26.2
-	-	-	-	-	-
End point					
-	-	-	-	-	-
651 - 675	31.8	26.8	26.2	28.3	32.3
676 - 700	14.2	12.6	13.9	13.8	5.4
-	-	-	-	-	-

The charts here and in the 1954 diesel-fuel survey report differ from those in the 1953 report in that the fuels are represented on a percentage basis rather than by numbers of samples, so the lengths of the bars are directly comparable.

TABLE 5.--Analyses of grade 1-D diesel fuel oils, 1955

Item	Marketed as: Diesel fuel oil, class 1/	Marketed as: Burner fuel oil A.S.T.M. D396 Grade	Distributed in districts 2/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D93 ° F.	Color Union A.S.T.M. D155 No.	Color Saybolt A.S.T.M. D156 No.	Viscosity at 100° F. 3/ Kinematic A.S.T.M. D445 cs.	Viscosity at 100° F. 3/ Saybolt A.S.T.M. D88 Sec.	Cloud test A.S.T.M. D97 ° F.	Pour point A.S.T.M. D97 ° F.	Sulfur content A.S.T.M. D129 percent	Aniline point A.S.T.M. D611 ° F.	Carbon Res. 4/ A.S.T.M. D524 on 10% Res., %	Corrosion A.S.T.M. D130 5/ 3 hours at 122° F. and 212° F.	Ash A.S.T.M. D482 percent	Cetane number A.S.T.M. D613	Calculated Cetane Index A.S.T.M. D975	Distillation 6/ A.S.T.M. D86 Temperature ° F. IBP	% recovered 10	% recovered 50	% recovered 90	End point
Eastern region: Districts A, B, and C																								
1	1	1	A, B -	41.9	131	-	23	1.68	-	-	-50	0.06	-	0.08	-, 1	-	47	47.2	335	372	426	489	535
2	1	1	A, B, D, C, E	44.6	144	1	25	1.63	-	-36	-40	.07	154.0	.03	0, 0	<0.001	58	54.0	351	382	432	498	536
3	1, 2, 3	2	A, B, D, C, E	38.0	162	1	-	2.31	33.7	-14	-30	.29	146.4	.11	1, 1	< .001	54	48.6	362	416	480	566	620
4	1	1	A, D, B	41.5	7/140	-	29	1.73	-	<-10	< -10	.03	140	.05	1, -	.001	47.0	48.0	353	385	435	495	535
5	1	1	A, D, B ·	41.9	7/135	-	27	1.58	-	<-10	< -10	.027	148	.01	1, -	.001	46.0	46.8	346	380	424	478	510
6	1	-	B	37.1	164	1	-	2.38	34.0	-6	-10	.08	149.0	.08	-, 1	-	52	48.5	368	430	490	548	590
7	1, 2	-	B	38.4	160	1	-	2.16	33.2	-5	<-20	.11	148.1	.10	-, 1	-	49	48.4	338	398	473	568	621
8	3	-	B	33.6	180	2½	-	2.11	33.0	-24	-25	8/ 1.00	116.6	.13	1, -	.008	8/ 38.4	8/ 37.2	398	436	464	528	611
9	1	1	B	44.6	140	1	25	1.65	-	-40	-45	.06	152.3	.09	0, 1	.003	59	55.0	359	382	437	502	537
10	1	1	B, A, C	44.0	138	1	26	1.64	-	-25	-40	.07	151.5	.09	0, 1	.001	54	52.5	357	382	431	500	543
11	1, 2, 3	2	B, A, C	38.4	160	1	5	2.56	34.6	-3	-10	.43	154.0	.09	0, 0	.001	56	53.6	364	428	504	582	621
12	1	1	B, A, C, D	41.4	7/137	-	24	1.83	32	-	-	.062	-	-	1, -	.000	-	50.0	340	395	447	510	546
13	1	(9)	B, C, D	41.8	144	-	26	1.57	-	-40	-45	.096	140	.07	0, 1	.000	46.1	46.5	340	355	423	485	515
14	2, 3	-	B, C, D, A	40.3	138	1	-	1.80	-	-10	-20	.14	141	.10	1, 1	.001	50	48.0	330	384	449	532	598
15	1	1	B, C, D, A	42.1	130	1	1	1.70	-	-10	-20	.05	145	.06	1, 1	.001	53	48.7	342	377	432	500	542
16	3	-	B, D, A	33.3	160	2	-	2.77	35.3	5	0	.16	135	8/ .17	-, 1	.001	46.0	46.0	336	438	524	588	622
17	1, 2	1	C	46.5	152	-	21	1.70	31.5	-14	-35	.08	158.5	.10	1, 1	.001	56	56.3	380	401	422	453	508
18	1, 2, 3	2	C	45.8	158	1	-	2.13	33.1	-2	-20	.10	162.3	.14	1, 1	.001	58	56.3	380	400	430	500	622
19	1, 2	1	C	43.3	132	-	22	-	-	-	< 0	.107	-	< .06	1, -	.000	-	46.7	339	369	408	473	512
20	1, 2, 3	2	C	38.1	168	1	-	2.68	35.0	-	-5	.18	-	.10	-, 1	.000	-	55.5	382	434	520	586	620
21	1, 2	1	C	42.8	134	-	23	-	-	-	-20	.11	147.1	< .06	1, -	-	-	47.8	345	373	419	479	524
22	1, 2, 3	2	C	37.2	208	-	-	3.12	36.4	-	0	.15	159.8	< .06	-, 1	-	-	52.8	428	474	515	567	614
23	1, 2	1	C	45.0	140	-	23	1.68	31.4	-	<-20	.104	155	.06	1, -	.000	-	52.5	350	380	420	480	521
24	1, 2	1	C	43.3	132	-	24	-	-	<-30	<-30	.14	-	.08	1, -	-	-	50.8	340	378	430	491	526
25	3	-	C	34.1	154	1	-	2.38	34.0	4	0	.23	-	.15	-, 1	-	-	45.5	329	433	510	580	622
26	1, 2	1	C	42.2	142	-	13	1.70	-	-48	-50	.06	147.0	.02	2, 2	.000	52.1	48.8	357	394	431	486	522
27	1, 2	1	C	42.8	142	-	22	1.66	-	-48	-45	.08	147.6	.06	1, 2	.000	50.8	49.6	355	388	429	482	532
28	1	1	C	46.5	114	-	-	1.63	-	<-20	<-20	.12	168.8	-	1, 1	.0	-	57.5	345	399	428	475	508
29	1	1	C	46.3	165	-	18	1.73	31.6	-10	-10	.1	163.1	-	-, -	-	58	57.2	372	404	429	470	520
30	1	1	C	46.1	144	-	22	1.68	-	-	-	.048	160	.06	1, -	.0	-	56.8	351	377	429	493	542
31	2, 3	2	C	40.2	160	-	-1	2.75	35.2	12	0	.13	165	.06	1, -	.0	-	58.0	367	435	507	582	622
32	3	2	C	44.0	162	1	16	2.3	33.7	-4	-15	.07	165	.03	1, 1	.000	60.0	59.5	364	409	468	574	609
33	1, 2	1	C	48.4	135	-	10	1.40	30.4	-50	-60	.03	159.6	.04	1A, 1A	.000	-	54.3	330	354	392	464	519
34	1, 2	1	C	45.2	130	-	30	1.54	30.9	<-10	<-10	.10	150	.07	0, 0	.001	50.4	51.0	314	372	410	476	528
35	1, 2, 3	2	C	40.0	168	1	-	2.65	34.9	2	0	.13	158	.08	0, 0	.001	55.0	57.4	378	440	506	566	618
36	3	2	C	33.9	155	1	-	2.47	34.3	4	0	.19	138	.10	0, 0	.001	42.5	44.0	368	442	504	572	618
37	1, 2	1	C, B	43.7	127	1	-	1.42	30.4	<-16	<-20	.13	152.6	.11	1A, 1A	<.001	50	49.3	331	373	417	507	606
38	1	(9)	C, B, A	45.6	146	-	26	1.66	-	-44	-45	.066	155.6	.04	0, 1	.000	56.9	52.2	348	376	412	468	510
39	1	1	C, E	42.4	142	1	25	1.72	-	-42	-45	.09	148.7	.02	0, 1	<.001	49	50.6	351	385	439	508	551
40	1, 2, 3	2	C, E	39.4	150	1	18	2.44	34.2	-10	-20	.12	155.8	.04	0, 0	<.001	52	54.0	357	423	494	562	613
41	1	1	C, E	40.6	150	-	21	2.0	32.6	-10	-30	.08	157	.07	1A, 1B	.001	53.6	51.5	346	402	464	550	568
42	1, 2	1	C, E	43.4	125	-	25	1.57	31.0	-56	-60	.219	143	.080	1A, 1B	.00	51.0	50.6	342	384	428	484	532
43	1, 2	1	C, E	42.1	126	1	-	1.69	31.5	<-10	<-10	.13	146.5	.082	0, 0	.001	48.0	48.0	336	372	428	514	576
44	1	1	C, E	44.1	136	(Green)		1.7	31.6	<-25	<-25	.214	-	.07	1, 1	.000	53	51.5	320	365	424	496	552
45	2, 3	-	C, E	33.6	162	1	-	2.47	34.3	0	-5	.478	153.8	.10	1, 1	.000	46	45.0	368	448	514	572	622
46	1	1	C, E, A	42.8	142	1	22	1.61	-	-42	-50	.07	145.5	.08	0, 2	< .001	49	49.3	355	388	428	479	509
47	1	1	C, E, A	42.7	142	1	19	1.60	-	-54	-60	.06	145.8	.08	0, 1	<.001	51	49.2	349	391	428	490	508
48	1, 2, 3	2	C, E, A	39.8	165	1	16	2.32	33.9	-14	-20	.09	155.1	.09	0, 0	<.001	53	54.5	365	423	491	554	597
49	2, 3	2	C, E, A	35.1	146	1½	-	2.45	34.3	-5	-15	.19	137.5	.10	0, 0	.001	45	46.0	355	428	500	569	608
50	4	2	C, E, A	25.7	220	2	-	3.17	36.6	8	5	.37	102.0	8/ .30	0, 0	<.001	8/ 33	8/ 32.8	435	489	537	591	619

54	2,3	2	D, B	33.3	182	1	-	2.68	35.0	0	-5	.22	136.6	.00	1, 1	.000	45.0	43.7	372	450	510	579	620
55	1	1	D, B, A	43.3	132	1	-	1.59	-	-44	-55	.04	148.3	.13	1A, 2C	.001	49.9	49.0	332	372	420	486	518
56	2,3	2	D, B, A	34.5	160	2½	-	2.35	33.9	-6	-20	.31	152.2	8/ .17	1A, 1A	<.001	45.3	43.0	382	434	490	560	608
57	1, 2, 3(W)	-	D, E, C, G	39.0	166		(Dyed)	2.37	34.0	-10	-20	.12	155	.07	1A, 1A	.001	51.8	50.0	370	417	475	564	607
58	1, 2, 3(S)	-	D, E, C, G	38.4	188		(Dyed)	2.79	35.4	0	-10	.10	156	.06	1A, 1A	.001	52.4	50.8	402	441	488	560	612
59	1	1	D, E, C, G	42.8	140		(Dyed)	1.78	-	-10	-35	.048	150	.06	1A, 1A	.001	51.1	48.6	366	392	423	468	502
69	1	(9)	E, C, G	43.8	136	-	28	1.49	-	-46	-50	.065	146.3	.07	0, 1	.000	50.8	48.8	339	368	414	478	518
70	1	1	E, C, G	42.4	136	1	23	1.76	-	-16	-25	.06	151.0	.07	0, 1	.000	52.3	47.5	337	375	422	523	562
71	1, 2	-	E, F, C, G	43.5	7/128	-	26	1.52	-	-60	-70	.076	147.2	Trace	1A, 1A	.000	-	49.0	340	372	418	465	506
72	1, 2	1	E, F, C, G	39.9	7/134	1	-5	2.10	33.0	-8	-15	.150	156.2	do.	-, 1A	.000	54	50.3	350	392	466	560	616
73	1, 2, 3	2	E, F, C, G	36.1	7/135	1½	-	1.97	32.5	-	-15	8/ .580	138.2	do.	-, 1B	.000	47	43.1	345	375	470	555	625
74	1, 2, 3	-	E, F, C, G	38.8	175	1	-	2.68	35.0	-10	-15	.130	159.8	do.	-, 1A	.000	54	52.0	404	445	490	558	616
78	1	1	E, G, F, C, D	43.0	7/149	-	23	1.78	-	<-10	<-10	.12	147	.06	-, 1	.001	51.0	49.0	368	378	424	500	540
Average (63 samples)				40.9	-	-	-	2.02	32.7	-	-	0.127	149.4	0.074	-	0.000	51.3	50.4	356	401	454	521	567
Minimum				25.7	114	1	30	1.40	30.4	-60	-70	0.027	102.0	0.00	-	0.000	42.5	43.0	314	354	392	453	502
Maximum				48.4	220	2½	-5	3.17	36.6	12	5	.478	168.8	.15	-	.008	60.0	59.5	435	489	537	591	625

Southern region: Districts E, F, and G

51	1	(9)	D	41.9	134	-	30	1.58	-	-48	-50	0.027	139.6	-	0, 0	0.000	45.0	46.3	338	372	421	486	520
52	1	-	D	43.1	145	-	15	1.55	-	-40	-45	.04	147	0.07	1, -	.000	49.7	48.0	348	382	418	482	502
53	1	-	D	41.3	136	1	-	1.70	31.5	-20	-40	.09	151	.06	1, 1	.000	50.1	48.5	354	400	440	494	536
54	2,3	2	D, B	33.3	182	1	-	2.68	35.0	0	-5	.22	136.6	.00	1, 1	.000	45.0	43.7	372	450	510	579	620
55	1	1	D, B, A	43.3	132	1	-	1.59	-	-44	-55	.04	148.3	.13	1A, 2C	<.001	49.9	49.0	332	372	420	486	518
56	2,3	2	D, 8, A	34.5	160	2½	-	2.35	33.9	-6	-20	.31	152.2	8/ .17	1A, 1A	<.001	45.3	43.0	382	434	490	560	608
57	1, 2, 3(W)	-	D, E, C, G	39.0	166		(Dyed)	2.37	34.0	-10	-20	.12	155	.07	1A, 1A	.001	51.8	50.0	370	417	475	564	607
58	1, 2, 3(S)	-	D, E, C, G	38.4	188		(Dyed)	2.79	35.4	0	-10	.10	156	.06	1A, 1A	.001	52.4	50.8	402	441	488	560	612
59	1	1	D, E, C, G	42.8	140		(Dyed)	1.78	-	-10	-35	.048	150	.06	1A, 1A	.001	51.1	48.6	366	392	423	468	502
60	1	1	D, G, E	42.2	134	-	30	1.68	-	<-30	<-30	.016	150	.06	0, -	.000	51.2	48.2	340	374	428	491	530
61	1, 2	1	D, G, E	42.0	144	-	24	1.72	-	<-30	<-30	.048	149	.06	0, -	.000	47.6	48.0	360	386	429	491	528
62	1	(9)	D, G, J	44.6	138	-	26	1.49	-	-42	-50	.066	148.8	.06	0, 1	.000	50.6	50.7	342	373	415	472	503
2	1	1	A, 8, D, C, E	44.6	144	1	25	1.63	-	-36	-40	.07	154.0	.03	0, 0	<.001	58	54.0	351	382	432	498	536
3	1, 2, 3	2	A, 8, D, C, E	38.0	162	1	-	2.31	33.7	-14	-30	.29	146.4	.11	1, 1	<.001	54	48.6	362	416	480	566	620
4	1	1	A, D, 8	41.5	7/140	-	29	1.73	-	<-10	<-10	.03	140	.05	1, -	.001	47.0	48.0	353	385	435	495	535
5	1	1	A, D, B	41.9	7/135	-	27	1.58	-	<-10	<-10	.027	148	.01	1, -	.001	46.0	46.8	346	380	424	478	510
12	1	1	8, A, C, D	41.4	7/137	-	24	1.83	32	-	-	.062	-	-	1, -	.000	-	50.0	340	395	447	510	546
13	1	(9)	8, C, D	41.8	144	-	26	1.57	-	-40	-45	.096	140	.07	0, 1	.000	46.1	46.5	340	355	423	485	515
14	2, 3	-	8, C, D, A	40.3	138	1	-	1.80	-	-10	-20	.14	141	.10	1, 1	.001	50	48.0	330	384	449	532	598
15	1	1	8, C, D, A	42.1	130	1	1	1.70	-	-10	-20	.05	145	.06	1, 1	.001	53	48.7	342	377	432	500	542
16	3	-	8, D, A	33.3	160	2	-	2.77	35.3	5	0	.16	135	8/ .17	-, 1	.001	46.0	46.0	336	438	524	588	622
78	1	1	E, G, F, C, D	43.0	7/149	-	23	1.78	-	<-10	<-10	.12	147	.06	-, 1	.001	51.0	49.0	368	378	424	500	540
89	3	-	G, D	38.4	158	1	-	2.50	34.4	-10	-15	.46	156	.10	1, 1	.000	55	54.3	358	438	508	572	622
129	3	-	G, J, D	39.3	168	1	-	2.56	34.6	-18	-20	.13	164	.08	-, 1	.001	55	53.5	380	445	492	558	607
Average (24 samples)				40.5	-	-	-	1.96	32.5	-	-	0.115	147.8	0.065	-	0.000	50.0	48.7	355	399	451	517	557
Minimum				33.3	130	1	30	1.49	-	-48	-55	0.016	135	0.00	-	0.000	45.0	43.0	,0	355	415	468	502
Maximum				44.6	188	2½	1	2.79	35.4	5	0	.46	164	.13	-	.001	58	54.3	402	450	524	588	622

1/ Classes 1, 2, 3, and 4 of diesel fuel oils are described in the text. (S) or (W) indicates the fuel is recommended for use only during the summer or winter season, respectively.

2/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of distribution of the fuel. Fuels listed above the line separating items 50 and 54 are generally sold in greatest volume in the Eastern region. Fuels listed above the line separating items 62 and 2 are generally sold in greatest volume in the Southern region. The fuels listed below the lines are generally sold in lesser volumes in the two respective regions than in some other region.

3/ Viscosities reported in one term were converted to equivalent figures in the other, where possible, as explained in the text, page 9. The Saybolt viscosity given in the average is the equivalent of the kinematic viscosity average.

4/ Some of the determinations were made by the Conradson method, ASTM D189-52, and the data were converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

5/ Corrosion test results are given separately for the two temperatures by number according to ASTM D130-53T or ASTM D130-54T.

6/ Distillation figures have been converted, where necessary, to temperatures at 760 mm. Hg according to table 1 in ASTM D86-52.

7/ Flash point by Tag closed tester, ASTM D56-52.

8/ Not within specification of fuels for this grade, figure not included in average.

9/ Offered as kerosine.

TABLE 5.--Analyses of grade 1-D diesel fuel oils, 1955 (Cont.)

Central region: Districts E, F, and G

Item	Marketed as: Diesel fuel oil, class 1/	Marketed as: Burner fuel oil A.S.T.M. D396 Grade	Distributed in districts 2/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D93 ° F.	Color: Union A.S.T.M. D155 No.	Color: Saybolt A.S.T.M. D156 No.	Viscosity at 100° F. 3/: Kinematic A.S.T.M. D445 cs.	Viscosity at 100° F. 3/: Saybolt A.S.T.M. D88 Sec.	Cloud test A.S.T.M. D97 ° F.	Pour point A.S.T.M. D97 ° F.	Sulfur content A.S.T.M. D129 percent	Aniline point A.S.T.M. D611 ° F.	Carbon Res. 4/ A.S.T.M. D524 on 10% Res., %	Corrosion A.S.T.M. D130 5/ 3 hours at 122° F. and 212° F.	Ash A.S.T.M. D482 percent	Cetane number A.S.T.M. D613	Calculated Cetane Index A.S.T.M. D975	Distillation 6/ A.S.T.M. D86, Temperature ° F.: IBP	% recovered: 10	50	90	End point
63	1,2	1	E	42.6	128	-	23	1.69	-	-36	-40	0.26	147.8	0.09	1,2	0.000	53.6	50.7	325	381	437	517	568
64	2,3	2	E	38.5	174	-	9	3.12	36.4	4	0	.38	164.0	.14	1,1	.000	57.2	58.1	383	477	530	574	624
65	1,2	1	E	42.3	131	-	25	1.7	-	-34	-40	.10	147	.08	1A,1A	.00	50.0	49.0	341	381	431	518	580
66	1	1	E	42.3	133	-	30	1.64	-	<-50	<-50	7/ .09	147.6	.06	1,1	.000	51.0	47.3	346	378	422	470	510
67	1	1	E	40.8	146	-	21	2.09	33.0	-45	<-50	7/ .11	152.2	.06	1,1	.000	53.2	50.8	358	404	458	536	570
68	1	2	E	36.4	166	2	-	2.38	34.0	-5	-15	7/ .19	143.6	.09	1,1	.000	48.3	46.5	368	430	486	556	618
69	1	(8)	E,C,G	43.8	136	-	28	1.49	-	-46	-50	.065	146.3	.07	0,1	.000	50.8	48.8	339	368	414	478	518
70	1	1	E,C,G	42.4	136	1	23	1.76	-	-16	-25	.06	151.0	.07	0,1	.000	52.3	47.5	337	375	422	523	562
71	1,2	-	E,F,C,G	43.5	9/ 128	-	26	1.52	-	-60	-70	.076	147.2	Trace	1A,1A	.000	-	49.0	340	372	418	465	506
72	1,2	1	E,F,C,G	39.9	9/ 134	1	-5	2.10	33.0	-8	-15	.150	156.2	do.	-,1A	.000	54	50.3	350	392	466	560	616
73	1,2,3	2	E,F,C,G	36.1	9/ 135	1½	-	1.97	32.5	-	-15	10/ .580	138.2	do.	-,18	.000	47	43.1	345	375	470	555	625
74	1,2,3	-	E,F,C,G	38.8	175	1	-	2.68	35.0	-10	-15	.130	159.8	do.	-,1A	.000	54	52.0	404	445	490	558	616
75	1,2,3(W)	-	E,G	39.9	152	(Copper)		2.23	33.5	-15	-25	7/ .13	153.0	.08	1,1	.000	53.3	51.7	362	418	474	544	602
76	1,2,3(S)	-	E,G	38.6	158	(Copper)		2.69	35.0	-10	-15	7/ .14	156.9	.08	1,1	.000	54.6	53.8	348	438	502	592	619
77	2,3	-	E,G	36.1	160	1½	-	2.25	33.5	5	-5	.36	139	10/ .22	-,1	.001	48.0	46.5	366	422	490	566	624
78	1	1	E,G,F,C,D	43.0	9/ 149	-	23	1.78	-	<-10	<-10	.12	147	.06	-,1	.001	51.0	49.0	368	378	424	500	540
79	1,2	-	F,H,E	43.7	9/ 132	-	22	-	-	-	-	.087	-	-	-,1A	-	-	46.5	338	365	404	457	504
80	1,2	1	F,H,E	39.8	150	-	10	-	-	-	-20	-	-	.06	-,2A	-	51.8	51.3	344	385	473	556	604
81	1,2,3	2	F,H,E	36.2	9/ 138	1	-	2.19	33.3	-	-20	-	-	.07	1A,18	-	44.8	43.3	331	378	470	563	614
82	1,2	-	G	44.1	9/ 123	-	26	-	-	-	-	.110	147.2	-	1A,1A	-	-	50.0	330	364	417	470	503
83	1,2	1	G	42.7	9/ 128	-	19	2.10	33.0	-	-25	.072	150.1	.12	1A,18	-	-	50.3	330	376	434	494	542
84	1,2,3	-	G	38.5	175	1	-	2.83	35.5	0	-5	.177	161.6	.10	-,1A	-	54.7	54.7	390	442	509	569	603
85	-	2	G	33.8	175	1½	-	2.38	34.0	-1	-5	.28	131.2	.136	1,1	.002	-	43.1	365	438	500	575	624
86	3	-	G	35.1	176	1	-	2.31	33.7	-12	-10	.14	135.2	.11	1A,1A	.000	45.7	44.3	380	432	490	554	588
87	3	-	G	36.9	157	1	-	2.09	33.0	-15	-20	.103	137.3	.14	1,1	.001	-	45.0	366	415	472	537	582
88	3	-	G	41.4	154	1	-	2.08	32.9	-20	-25	.081	155.8	.09	1,1	.001	-	52.7	369	408	462	540	590
89	3	-	G,D	38.4	158	1	-	2.50	34.4	-10	-15	.46	156	.10	1,1	.000	55	54.3	358	438	508	572	622
90	1,2	-	G,E	44.2	9/ 131	-	23	-	-	-	-	.057	147.2	-	1A,18	-	-	48.3	350	368	407	460	504
91	1,2	1	G,E	42.5	9/ 134	-	16	2.10	33.0	-30	-35	.134	149	.06	-,18	-	53.0	49.5	346	375	431	506	546
92	1,2,3	2	G,E	38.5	9/ 142	-	-	2.68	35.0	-	-10	.270	141.8	.13	-,18	-	49.0	49.3	360	398	477	562	616
93	1,2,3	-	G,E	39.5	155	1	-	2.99	36.0	-18	<-20	.185	149	.06	-,18	.00	52.0	50.5	382	423	473	531	580
94	3	-	G,E	32.9	168	1½	-	2.99	36.0	-	0	.355	138.2	-	-,-	-	44.0	43.0	397	448	510	578	612
95	2,3	-	G,E,F	38.9	190	1	-	2.80	35.4	-5	-5	.08	162	.09	-,1	.000	55	54.8	406	460	505	552	598
96	3	-	G,E,F	40.8	165	1	-	2.30	33.7	-15	-15	.08	160	.08	-,1	.000	54	54.0	352	418	476	550	600
97	1,2	1	G,E,F	42.2	146	1	19	1.86	32.1	-26	-35	.04	154.5	.05	1A,1A	.000	51	50.8	364	396	442	520	562
98	2	2	G,E,F	31.9	162	1	-	2.43	34.2	-4	-5	.22	124.0	.11	1A,1A	.001	41	40.6	348	433	508	562	598
99	1,2	1	G,E,F	44.2	134	-	29	1.54	-	-44	-55	.08	150	.008	0,-	.001	51.1	50.1	345	368	416	479	513
100	1,2	1	G,E,F	43.9	135	-	22	1.83	32.0	-22	-30	.084	159	.038	0,-	.000	58.5	56.0	355	389	450	524	557
101	2,3	2	G,E,F	35.0	160	1	-	2.55	34.6	6	0	.26	142	.096	0,1	.000	46.7	47.8	366	438	514	574	619
102	2,3	2	G,E,F	35.9	157	1	-	2.27	33.6	0	-5	.253	136.5	.087	0,-	.000	45.6	47.9	353	416	501	569	615
103	2,3(W)	-	G,E,F	37.6	159	1	-	2.46	34.3	2	-5	.19	150	.13	0,0	.001	52.3	51.0	366	438	500	570	602
104	2,3(W)	-	G,E,F	37.5	159	1	-	2.38	34.0	-4	-15	.211	145.5	.11	-,1	.000	49.8	50.2	364	424	496	562	599
105	1,2	1	G,E,F,J,I	42.1	156	-	20	1.94	32.4	-18	-25	.153	153	<.06	0,-	.000	55.1	52.6	368	402	453	517	554
106	2,3	2	G,E,F,J,I	36.3	156	1½	-	2.27	33.6	0	-10	.295	136	.08	-,0	.000	43.8	47.7	360	414	495	564	604
107	2,3(W)	-	G,E,J,I	41.5	156	1	-	2.13	33.1	-6	-15	.252	155	<.06	-,0	.000	55.5	54.7	350	402	471	552	584
108	1,2,3(W)	-	G,F	38.4	198	1	-	2.50	34.4	-18	-20	.132	154	.098	-,1	.000	51.4	51.8	431	458	493	547	574
109	1,2,3(S)	-	G,F	38.6	202	1	-	2.60	34.8	-12	-15	.152	157	.096	-,1	.000	53.4	52.3	431	461	494	546	582
110	1	1	G,F	41.7	148	1	23	1.60	-	-54	-60	.083	142	.095	1,-	.000	50.1	45.8	365	388	421	474	514
111	2,3	2	G,F	36.5	182	-	-	2.19	33.3	-22	-25	.309	136	.152	-,1	.001	45.5	46.0	401	431	483	537	558
112	1,2,3	-	G,F	41.0	155	-	20	2.31	33.7	-15	-20	.13	155	.09	1,1	.000	-	53.6	366	420	472	535	562

113	1,2,3	-	G,F	40.4	160	1	-	2.16	33.2	-6	-20	.147	-	Trace	1A,1A	-	52.0	50.3	384	425	460	545	617
114	1	1	G,F,E	43.2	136	-	27	1.69	-	-46	-50	.080	152	.062	0,0	.000	50.7	51.0	350	382	432	492	529
115	1,2	2	G,F,E	42.0	144	-	20	2.02	32.7	-23	-25	.067	157	.058	0,0	.000	51.6	53.7	346	392	460	542	596
116	1,2	1	G,F,E	42.2	144	-	23	2.19	33.3	-30	-35	.063	156	.061	0,0	.000	52.7	52.0	360	396	448	533	566
117	2,3	2	G,F,E	33.0	156	1½	-	2.55	34.6	-3	-5	.191	129	.129	0,0	.002	40.6	42.8	350	434	508	574	622
118	1	(8)	G,F,E	45.7	142	-	30	1.64	-	-50	-55	.11	160.9	.07	0,1	.000	53.8	55.0	348	379	424	484	525
119	1	1	G,F,E	41.9	136	-	21	1.71	-	-40	-50	.50	146.1	.06	0,1	.000	49.0	48.3	338	370	432	516	566
120	2,3	-	G,F,E	38.1	178	(Dyed Red)		3.05	36.2	-	-5	7/ .164	162	.072	1,1	.000	55.5	57.5	378	437	532	585	617
121	3(W)	-	G,F,E	41.9	155	5	-	2.02	32.7	-	-30	7/ .087	153	.030	1,1	.000	54.7	52.2	357	406	453	502	542
122	2,4	2	G,F,E	35.0	174	1	-	2.52	34.5	-	-10	7/ .395	137	10/ .161	1,1	.000	42.9	46.0	375	431	502	560	591
123	2,3	2	G,F,E	33.6	143	1	-	2.33	33.8	-	-5	.29	-	10/ .16	0,-	.000	-	43.6	326	393	505	583	620
124	1,2	1	G,F,E	42.2	136	-	26	1.91	32.3	-	-30	.18	-	.05	0,-	.000	-	53.4	344	383	456	522	550
125	1,2	-	G,I,F	43.7	9/ 131	-	27	-	-	-	-	.103	-	-	1A,2A	-	-	49.3	346	377	417	462	501
126	1,2	1	G,I,F	43.0	9/ 132	-	14	1.80	31.9	-	< -40	.143	-	Trace	1A,2A	-	-	47.8	340	376	417	476	536
127	1,2,3	2	G,I,F	35.6	134	1½	-	2.59	34.7	-	-10	.379	-	.06	1A,2A	-	46.8	45.3	347	414	489	550	601
128	3	-	G,J	37.4	210	1	-	3.34	37.1	-5	-5	.12	166	.09	-,1	.001	56	54.2	453	491	521	569	617
129	3	-	G,J,D	39.3	168	1	-	2.56	34.6	-18	-20	.13	164	.08	-,1	.001	55	53.5	380	445	492	558	607
2	1	1	A,B,D,C,E	44.6	144	1	25	1.63	-	-36	-40	.07	154.0	.03	0,0	<.001	58	54.0	351	382	432	498	536
3	1,2,3	2	A,B,D,C,E	38.0	162	1	-	2.31	33.7	-14	-30	.29	146.4	.11	1,1	<.001	54	48.6	362	416	480	566	620
39	1	1	C,E	42.4	142	1	25	1.72	-	-42	-45	.09	148.7	.02	0,1	<.001	49	50.6	351	385	439	508	551
40	1,2,3	2	C,E	39.4	150	1	18	2.44	34.2	-10	-20	.12	155.8	.04	0,0	<.001	52	54.0	357	423	494	562	613
41	1	1	C,E	40.6	150	-	21	2.0	32.6	-10	-30	.08	157	.07	1A,1B	.001	53.6	51.5	346	402	464	550	568
42	1,2	1	C,E	43.4	125	-	25	1.57	31.0	-56	-60	.219	143	.080	1A,1B	.00	51.0	50.6	342	384	428	484	532
43	1,2	1	C,E	42.1	126	1	-	1.69	31.5	<-10	<-10	.13	146.5	.082	0,0	.001	48.0	48.0	336	372	428	514	576
44	1	1	C,E	44.1	136	(Green)		1.7	31.6	<-25	<-25	.214	-	.07	1,1	.000	53	51.5	320	365	424	496	552
45	2,3	-	C,E	33.6	162	1	-	2.47	34.3	0	-5	.478	153.8	.10	1,1	.000	46	45.0	368	448	514	572	622
46	1	1	C,E,A	42.8	142	1	22	1.61	-	-42	-50	.07	145.5	.08	0,2	<.001	49	49.3	355	388	428	479	509
47	1	1	C,E,A	42.7	142	1	19	1.60	-	-54	-60	.06	145.8	.08	0,1	<.001	51	49.2	349	391	428	490	508
48	1,2,3	2	C,E,A	39.8	165	1	16	2.32	33.9	-14	-20	.09	155.1	.09	0,0	<.001	53	54.5	365	423	491	554	597
49	2,3	2	C,E,A	35.1	146	1½	-	2.45	34.3	-5	-15	.19	137.5	.10	0,0	.001	45	46.0	355	428	500	569	608
50	4	2	C,E,A	25.7	220	2	-	3.17	36.6	8	5	.37	102.0	10/ .30	0,0	<.001	10/ 33	10/ 32.8	435	489	537	591	619
57	1,2,3(W)	-	D,E,C,G	39.0	166	(Dyed)		2.37	34.0	-10	-20	.12	155	.07	1A,1A	.001	51.8	50.0	370	417	475	564	607
58	1,2,3(S)	-	D,E,C,G	38.4	188	(Dyed)		2.79	35.4	0	-10	.10	156	.06	1A,1A	.001	52.4	50.8	402	441	488	560	612
59	1	1	D,E,C,G	42.8	140	(Dyed)		1.78	-	-10	-35	.048	150	.06	1A,1A	.001	51.1	48.6	366	392	423	468	502
60	1	1	D,G,E	42.2	134	-	30	1.68	-	<-30	<-30	.016	150	.06	0,-	.000	51.2	48.2	340	374	428	491	530
61	1,2	1	D,G,E	42.0	144	-	24	1.72	-	<-30	<-30	.048	149	.06	0,-	.000	47.6	48.0	360	386	429	491	528
62	1	(8)	D,G,J	44.6	138	-	26	1.49	-	-42	-50	.066	148.8	.06	0,1	.000	50.6	50.7	342	373	415	472	503
143	1,2,3(W)	-	I,G,H,K	38.2	160	-	17	2.55	35.0	-4	-15	.497	152.5	.08	1,1	<.001	-	50.6	382	433	489	571	616
144	1,2,3(S)	-	I,G,H,K	38.1	166	-	5	2.65	35.0	-8	-10	.440	154.5	.08	1,1	.001	-	51.2	384	439	494	573	618
148	1	(8)	I,K,H,F	45.1	132	-	27	1.50	-	<-20	<-20	.12	146	.02	0,1	.000	46.2	48.0	352	368	396	466	528
149	1	1	I,K,H,F	44.7	130	1	22	1.54	-	<-20	<-20	.23	146	.03	0,1	.000	48.7	47.0	335	350	394	490	549
150	2	2	I,K,H,F	37.9	156	1	-	2.81	35.4	-5	-10	10/ .64	154	.088	0,0	.000	53.4	51.4	378	422	498	582	612
155	1,2	1	J,G	38.8	162	1	-	2.0	32.6	-20	-30	.43	139	.12	0,-	.004	-	46.0	387	423	455	497	528
156	1,2,3(W)	-	J,G,I	41.6	164	(Amber)		2.19	33.3	-5	-10	.120	157	.08	-,1	.000	-	53.7	389	419	464	547	599
157	1,2	1	J,I,G	42.8	141	-	29	1.80	31.9	-28	-30	.113	152	<.06	0,-	.000	53.6	53.0	358	398	447	493	529
Average (95 samples)				39.9	-	-	-	2.18	33.3	-	-	0.176	148.8	0.079	-	0.000	50.9	49.8	362	407	464	532	575
Minimum				25.7	125	1	30	1.49	-	-60	-70	0.016	102.0	0.008	-	0.000	40.6	40.6	320	350	394	457	501
Maximum				45.7	220	5	-5	3.34	37.1	8	5	.497	166	.152	-	.004	58.5	58.1	453	491	537	592	625

1/ Classes 1, 2, 3, and 4 of diesel fuel oils are described in the text. (S) or (W) indicates the fuel is recommended for use only during the summer or winter season, respectively.

2/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of distribution of the fuel. Fuels listed above the line separating items 129 and 2 are generally sold in greatest volume in the Central region. The fuels listed below the line are generally sold in lesser volume in this region than in some other region.

3/ Viscosities reported in one term were converted to equivalent figures in the other, where possible, as explained in the text, page 9. The Saybolt viscosity given in the average is the equivalent of the kinematic viscosity average.

4/ The figures shown are Ramsbottom carbon residues. Some of the determinations were made by the Conradson method, ASTM D189-52, and the data were converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

5/ Corrosion test results are shown by number according to ASTM D130-53T and ASTM D130-54T.

6/ Distillation figures have been converted, where necessary, to temperatures at 760 mm Hg according to table 1 in ASTM D86-52.

7/ Determined by lamp method, ASTM D1266-53T.

8/ Offered as kerosine.

9/ Flash point by Tag closed tester, ASTM D56-52.

10/ Not within specification of fuels of this grade, figure not included in average.

TABLE 5. --Analyses of grade 1-D diesel fuel oils, 1955 (Cont.)

Item	Marketed as: Diesel fuel oil, class 1/	Marketed as: Burner fuel oil A.S.T.M. D396 Grade	Distributed in districts 2/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D93 ° F.	Color Union A.S.T.M. D155 No.	Color Saybolt A.S.T.M. D156 No.	Viscosity at 100° F. 3/ Kinematic A.S.T.M. D445 cs.	Viscosity at 100° F. 3/ Saybolt A.S.T.M. D88 Sec.	Cloud test A.S.T.M. D97 ° F.	Pour point A.S.T.M. D97 ° F.	Sulfur content A.S.T.M. D129 percent	Aniline point A.S.T.M. D611 ° F.	Carbon Res. 4/ A.S.T.M. D524 on 10% Res., %	Corrosion A.S.T.M. D130 5/ 3 hours at 122° F. and 212° F.	Ash A.S.T.M. D482 percent	Cetane number A.S.T.M. D613	Calculated Cetane Index A.S.T.M. D975	Distillation 6/ A.S.T.M. D86 Temperature ° F. IBP	% recovered 10	% recovered 50	% recovered 90	End point
Rocky Mountain region: Districts H, I, J, and K																								
130	1,2	1	H	41.4	160	1	-	1.69	-	-40	-40	0.338	147	0.008	0,-	<0.001	52.1	46.5	374	389	428	496	545
131	3(W)	-	H	39.4	160	1	-	2.10	33.0	-18	-20	.492	149	.004	0,0	< .001	50.8	50.0	370	413	471	563	614
132	1	1	H, L	43.8	138	-	30	1.47	-	<-30	<-30	7/ .086	139	.06	1,1	.000	49.2	48.0	348	370	409	465	496
133	1	1	H, L	41.7	144	-	21	1.73	-	<-30	<-30	7/ .248	144	.06	1,1	.000	51.2	49.2	372	391	439	516	567
134	2,3	-	H, L	37.9	170	1	-	2.57	34.7	0	-15	.50	154	.08	-,1	.001	53	51.8	389	439	500	574	625
135	2,3	-	I	39.9	168	1	-	2.38	34.0	0	-5	.05	162	.08	-,1	.000	54	55.0	377	438	494	582	620
136	2,3	-	I	39.5	158	1	-	2.17	33.2	-5	-10	.06	154	.09	-,1	.000	53	52.7	359	415	485	578	617
137	2,3	2	I	41.0	145	1	-	1.88	32.2	-10	-15	.05	162	.10	1,-	.000	53	53.3	330	391	470	560	600
138	2,3(S)	2	I	39.6	186	1	-	2.57	34.7	5	-5	.08	160	.08	-,1	.000	57	57.4	407	453	511	569	602
139	2,3(W)	2	I	39.5	156	1	-	2.26	33.6	-10	-15	.07	154	.08	-,1	.000	52	52.7	359	430	485	556	600
140	1	-	I	43.0	150	1	-	1.64	-	-50	-60	.02	144	.06	1,-	.000	50	50.3	370	390	430	475	518
141	2,3	-	I	39.4	161	(Dyed Red)		1.97	32.5	-	-40	7/ .056	135	.105	1,1	.000	47.8	45.5	372	410	445	493	538
142	3	-	I, J	33.0	164	1½	-	2.73	35.2	6	0	.20	117	.12	-,1	.001	45	44.7	380	459	520	580	620
143	1,2,3(W)	-	I, G, H, K	38.2	160	-	17	2.55	35.0	-4	-15	.497	152.5	.08	1,1	<.001	-	50.6	382	433	489	571	616
144	1,2,3(S)	-	I, G, H, K	38.1	166	-	5	2.65	35.0	-8	-10	.440	154.5	.08	1,1	.001	-	51.2	384	439	494	573	618
145	1,2	-	I, H	41.6	8/ 140	-	21	-	-	-	-	.019	-	-	1A, 1B	-	-	46.0	364	390	423	465	496
146	2,1	1	I, H	41.0	8/ 145	-	13	1.81	31.9	-	-25	.078	145.4	.09	1A, 1A	-	-	47.3	370	404	437	495	548
147	1	1	I, K	42.1	138	-	29	1.71	31.2	<-20	<-20	.018	148.5	.06	1,1	Trace	-	50.3	353	395	440	489	527
148	1	(9)	I, K, H, F	45.1	132	-	27	1.50	-	<-20	<-20	.12	146	.02	0,1	.000	46.2	48.0	352	368	396	466	528
149	1	1	I, K, H, F	44.7	130	1	22	1.54	-	<-20	<-20	.23	146	.03	0,1	.000	48.7	47.0	335	350	394	490	549
150	2	2	I, K, H, F	37.9	156	1	-	2.81	35.4	-5	-10	10/ .64	154	.088	0,0	.000	53.4	51.4	378	422	498	582	612
151	2	-	J	38.0	170	1	-	3.08	36.3	10	-5	.50	156	.08	-,1	.001	53	49.5	381	433	485	559	619
152	2,3	-	J	38.2	170	1	-	3.30	37.0	10	-20	.37	146	.09	-,1	.000	52	50.4	377	431	488	565	624
153	1	-	J	42.4	117	1	-	1.52	-	-	<-30	10/ .085	145	.10	-,1	.00	50	47.1	337	362	420	477	561
154	1	1	J	43.3	138	(Yellow)		1.70	-	-32	-35	.096	146	.08	-,1	.00	-	51.4	353	393	433	489	524
155	1,2	1	J, G	38.8	162	1	-	2.0	32.6	-20	-30	.43	139	.12	0,-	.004	-	46.0	387	423	455	497	528
156	1,2,3(W)	-	J, G, L	41.6	164	(Amber)		2.19	33.3	-5	-10	.120	157	.08	-,1	.000	-	53.7	389	419	464	547	599
157	1,2	1	J, I, G	42.8	141	-	29	1.80	31.9	-28	-30	.113	152	<.06	0,-	.000	53.6	53.0	358	398	447	493	529
158	1	1	K, L	42.4	134	-	22	1.73	31.6	-50	-55	.16	150	.01	-,0	.001	46.9	48.8	343	385	429	493	541
159	1,2	2	K, L	37.4	168	1	-	3.02	36.1	0	-5	.41	161	.06	-,0	.002	52.7	54.4	367	442	522	584	621
160	1,2	-	K, M	42.0	140	-	1	1.8	-	-45	-45	.21	151.5	.06	-,1	.00	50.0	50.3	337	406	442	472	539
62	1	(9)	D, G, J	44.6	138	-	26	1.49	-	-42	-50	.066	148.8	.06	0,1	.000	50.6	50.7	342	373	415	472	503
105	1,2	1	G, E, F, J, I	42.1	156	-	20	1.94	32.4	-18	-25	.153	153	<.06	0,-	.000	55.1	52.6	368	402	453	517	554
106	2,3	2	G, E, F, J, I	36.3	156	1½	-	2.27	33.6	0	-10	.295	136	.08	-,0	.000	43.8	47.7	360	414	495	564	604
107	2,3(W)	-	G, E, J, I	41.5	156	1	-	2.13	33.1	-6	-15	.252	155	<.06	-,0	.000	55.5	54.7	350	402	471	552	584
125	1,2	-	G, I, F	43.7	8/131	-	27	-	-	-	-	.103	-	-	1A, 2A	-	-	49.3	346	377	417	462	501

126	1,2	1	G,I,F	43.0	8/132	-	14	1.80	31.9	-	-40	.143	-	Trace	1A,2A	-	-	47.8	340	376	417	476	536
127	1,2,3	2	G,I,F	35.6	134	1½	-	2.59	34.7	-	-10	.379	-	.06	1A,2A	-	46.8	45.3	347	414	489	550	601
128	3	-	G,J	37.4	210	1	-	3.34	37.1	-5	-5	.12	166	.09	-,1	.001	56	54.2	453	491	521	569	617
129	3	-	G,J,D	39.3	168	1	-	2.56	34.6	-18	-20	.13	164	.08	-,1	.001	55	53.5	380	445	492	558	607
161	1	1	L,M,N,H	42.5	132	-	30	1.76	31.8	-	-55	.06	158	.07	-,-	-	47.0	50.0	334	397	434	470	516
Average (41 samples)				40.5	-	-	-	2.15	33.2	-	-	0.196	150.1	0.070	-	0.000	51.1	50.2	365	409	460	524	570
Minimum				33.0	117	1	30	1.47	-	-50	-60	0.018	117	0.004	-	0.000	43.8	44.7	330	350	394	462	496
Maximum				45.1	210	1½	1	3.34	3.71	10	0	.50	166	.12	-	.002	57	57.4	453	491	522	584	625

Western region: Districts L, M, and N

161	1	1	L,M,N,H	42.5	132	-	30	1.76	31.8	-	-55	0.06	158	0.07	-	-	47.0	50.0	334	397	434	470	516
162	1,2	-	N	42.2	154	-	1	1.81	-	<-30	<-30	.09	160	.06	-,1	0.00	50.0	49.3	362	398	434	488	538
163	1,2	-	N,L,M	38.4	148	1	-	1.85	32.1	-30	-35	.09	136.5	.09	-,1	.00	51.0	44.3	352	397	450	523	578
164	1,2,3	-	N,L,M	42.3	164	1	-	2.3	33.7	-	<-20	.06	150	.06	-,1	.001	51.0	52.5	387	408	449	494	514
165	1,2,3	-	N,L,M	40.5	146	2	-	2.00	32.6	-	<-20	.31	156	.06	-,1	.001	50.0	49.0	352	411	452	502	542
166	1	-	N,M,L	38.8	148	1½	-	1.74	32.0	-44	-65	.25	134.5	.09	1,1	<.001	46	41.5	351	383	430	500	542
167	1	1	N,M,L	42.7	144	(Yellow)		1.61	-	-56	-60	.01	154.3	.03	1,1	<.001	48	50.5	360	394	435	476	504
168	-	1	N,M,L	39.7	165	1	-	2.01	32.7	-36	-40	.25	143.1	.06	1,1	<.001	47	46.8	396	414	449	503	545
132	1	1	H,L	43.8	138	-	30	1.47	-	<-30	<-30	7/ .086	139	.06	1,1	.000	49.2	48.0	348	370	409	465	496
133	1	1	H,L	41.7	144	-	21	1.73	-	<-30	<-30	7/ .248	144	.06	1,1	.000	51.2	49.2	372	391	439	516	567
134	2,3	-	H,L	37.9	170	1	-	2.57	34.7	0	-15	.50	154	.08	-,1	.001	53	51.8	389	439	500	574	625
158	1	1	K,L	42.4	134	-	22	1.73	31.6	-50	-55	.16	150	.01	-,0	.001	46.9	48.8	343	385	429	493	541
159	1,2	2	K,L	37.4	168	1	-	3.02	36.1	0	-5	.41	161	.06	-,0	.002	52.7	54.4	367	442	522	584	621
160	1,2	-	K,M	42.0	140	-	1	1.8	-	-45	-45	.21	151.5	.06	-,1	.00	50.0	50.3	337	406	442	472	539
Average (14 samples)				40.9	-	-	-	1.96	32.5	-	-	0.198	149.4	0.061	-	0.001	49.5	49.0	361	403	448	504	548
Minimum				37.4	132	1	30	1.47	-	-56	-65	0.01	134.5	0.01	-	0.000	46	41.5	334	370	409	465	496
Maximum				43.8	170	2	1	3.02	36.1	0	-5	.50	161	.09	-	.002	53	54.4	396	442	522	584	625

1/ Classes 1, 2, 3, and 4 of diesel fuel oils are described in the text. (S) or (W) indicates the fuel is recommended for use only during the summer or winter season, respectively.

2/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of distribution of the fuel. Fuels listed above the line separating items 160 and 62 are generally sold in greatest volume in the Rocky Mountain region. Fuels listed above the line separating items 168 and 132 are generally sold in greatest volume in the Western region. The fuels listed below the lines are generally sold in lesser volumes in the two respective regions than in some other region.

3/ Viscosities reported in one term were converted to equivalent figures in the other, where possible, as explained in the text, page 9. The Saybolt viscosity given in the average is the equivalent of the kinematic viscosity average.

4/ Some of the determinations were made by the Conradson method. ASTM D189-52, and the data were converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

5/ Corrosion test results are given by number according to ASTM D130-53T or ASTM D130-54T.

6/ Distillation figures have been converted, where necessary, to temperatures at 760 mm. Hg according to table 1 in ASTM D86-52.

7/ Determined by lamp method.

8/ Flash point by Tag closed tester, ASTM D56-52.

9/ Offered as kerosine.

10/ Not within specification of fuels for this grade, figure not included in average.

TABLE 6.—Analyses of grade 2-D diesel fuel oils with maximum pour point 0 °F, 1955

Item	Marketed as: Diesel fuel oil, class 1/	Marketed as: Burner fuel oil A.S.T.M. D396 Grade	Distributed in districts 2/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D93 ° F.	Color Union A.S.T.M. D155 No.	Viscosity at 100° F. 3/ Kinematic A.S.T.M. D445 cs.	Viscosity at 100° F. 3/ Saybolt A.S.T.M. D88 Sec.	Cloud test A.S.T.M. D97 ° F.	Pour point A.S.T.M. D97 ° F.	Sulfur content A.S.T.M. D129 percent	Aniline point A.S.T.M. D611 ° F.	Carbon Res. 4/ A.S.T.M. D524 on 10% Res., %	Corrosion A.S.T.M. D130 5/ 3 hours at 122° F. and 212° F.	Ash A.S.T.M. D482 percent	Cetane number A.S.T.M. D613	Calculated Cetane Index A.S.T.M. D975	Distillation 6/ A.S.T.M. D158 Temperature ° F. IBP	% recovered 10	% recovered 50	% recovered 90	End point
Eastern region:	Districts A, B, and C																					
169	3	-	A, B	34.3	178	1	3.02	36.1	22	0	0.10	142.7	0.11	-,1	-	47	45.7	370	435	509	608	667
170	-	2	A, B, C	37.5	-	1	2.70	35.1	5	0	.70	152	.07	1A, 1A	0.000	53.2	52.6	360	432	510	596	648
171	2,3	2	A, B, D, C, E	32.7	154	2½	2.57	34.6	2	-5	.50	131.2	.29	1,1	<.001	50	42.5	343	423	510	594	640
172	4	2	A, B, D, C, E	17.6	240	4½	4.39	40.4	-	-15	.27	62.0	7/ 1.14	1,1	.001	7/<25	7/ 14.6	472	506	552	648	700
173	3	-	B	34.1	146	2½	2.38	34.0	4	-10	.12	135.0	.19	1,1	<.001	43.0	41.9	340	418	488	566	654
174	2,3	-	B	34.6	196	1	3.11	36.4	10	0	.12	152.2	.10	1,1	<.001	50.0	48.3	408	484	522	580	646
175	1,2,3	-	B	38.6	190	(Red)	2.87	35.6	-2	0	.50	159.1	.08	1,-	.001	52.2	55.2	406	454	511	587	645
176	2,3	2	B	39.1	170	2	2.27	33.6	-12	-10	.59	148.1	.10	1,-	.005	51.4	50.5	386	423	477	575	643
177	2,3	2	B	35.9	146	2½	2.42	34.2	-6	-10	.57	140.9	.14	0,0	.005	50	47.6	352	419	500	590	649
178	2,3	2	B	38.3	155	1	2.29	33.7	-10	-40	.29	148.9	.09	0,0	.005	52	49.7	367	412	482	570	643
179	3	2	B, A, C	36.3	160	1	2.40	34.0	8	-5	.49	143.0	.04	0,0	.001	48	47.4	361	418	494	590	645
180	1,2,3	-	B, A, D, G	37.2	160	1	2.68	35.0	4	0	.20	155.8	.22	1,1	.002	54	53.0	346	414	516	594	638
181	1,2,3	-	B, C, A, D	37.7	162	1½	2.62	34.8	0	-10	.185	153	.02	-,1	.000	50.9	50.5	368	425	495	586	631
182	2	2	B, C, D	32.5	162	1	3.35	37.2	10	0	.55	140	.13	0,1	.000	47.8	43.2	351	436	517	597	657
183	3	-	B, C, D	37.1	172	1	2.75	35.2	10	0	.31	156	.045	0,0	.000	51.2	52.0	380	442	511	589	669
184	2,3	2	B, C, D, A	35.6	140	2	2.30	33.7	5	-5	.40	138	.14	1,1	.001	46	46.6	327	410	498	588	630
185	2,3,4	-	B, D, A	34.0	170	1½	2.75	35.2	0	0	.40	145	.06	1,3	.001	46.0	45.0	370	410	508	586	648
186	3	-	B, D, A	35.7	160	1½	3.00	36.0	5	0	.49	128.0	.11	-,1	.001	48.0	48.0	366	430	506	580	636
187	3	2	B, D, A, C	35.4	156	2	2.52	34.5	0	< 0	.41	141	.01	-,1	.000	47.7	46.2	356	421	498	588	638
188	2	2	C	32.2	158	2	2.38	34.0	-	-5	.23	-	.26	-,1	.000	-	41.0	379	431	507	593	640
189	3	-	C	35.5	162	2	2.68	35.0	-	-5	.20	-	.17	-,1	.000	-	48.8	371	437	513	589	630
190	2	2	C	32.9	159	1½	2.44	34.2	-	0	.32	133.9	.12	-,1	-	-	43.1	350	435	511	586	626
191	3	-	C	35.1	179	-	2.77	35.3	-	0	.25	140.0	.13	-,1	-	-	47.7	382	451	511	576	627
192	1,2,3	2	C	40.1	158	8/ 1	2.68	35.0	-	0	.32	169	.10	-,1	.002	-	57.7	366	420	507	612	670
193	2	2	C	37.7	155	1	2.68	35.0	2	0	.18	-	.34	-,1	.000	-	50.5	348	417	495	585	635
194	1,2,3	2	C	39.8	155	1	2.38	34.0	4	0	.17	-	.08	-,1	.000	-	55.1	346	414	495	580	632
195	2	2	C	44.7	126	-	2.09	33.0	-8	-15	.14	174.2	.02	1,1	.0	-	59.8	318	410	461	556	629
196	2,3	2	C	39.4	156	2	2.76	35.3	4	-5	.07	163.0	.02	1,1	.00	55.4	55.8	356	435	504	592	649
197	2,3	2	C	37.3	168	8/ 2	2.45	34.3	2	-10	.18	148.4	.01	1,1	.00	51.4	49.3	367	422	492	580	634
198	1,2,3	2	C	44.8	155	1½	2.52	34.5	-8	0	.03	175.6	.06	1A, 1A	.000	60	64.2	342	397	484	592	656
199	1,2,3	2	C	37.6	162	1	2.68	35.0	4	0	.18	152.5	.06	0,0	.001	51.0	52.8	372	440	510	580	634
200	1,2,3	2	C, B	40.2	130	1	2.19	33.3	3	-10	.19	158	.12	1A, 1A	.001	51.0	55.3	335	372	491	604	653
201	3	2	C, B	35.9	136	1½	2.71	35.1	8	-5	.35	145	.14	1A, 1A	.003	44	49.4	337	403	511	609	668
202	2	2	C, B, A	42.0	158	1	2.52	34.5	8	0	.09	166.1	.04	0,0	.000	58.5	59.0	370	416	489	579	634
203	1,2,3	2	C, E	38.1	150	8/12	3.16	36.5	2	-5	.284	158	.097	1A, 1A	.00	56.0	58.5	352	448	532	599	649
204	3	2	C, E	29.5	206	1	3.24	36.8	7	0	.21	120	.180	0,0	.001	7/ 39.0	7/ 39.2	460	486	530	590	648
205	1,2,3	2	C, E	34.5	154	1	3.05	36.2	8	0	.17	148	.100	0,0	.001	47.0	50.8	340	432	540	598	664
206	1,2,3	2	C, E	31.9	174	1	3.27	36.9	7	0	.27	138.5	.120	0,0	.001	44.0	44.8	372	464	536	594	652
211	1,2,3	-	D, B, A	37.5	188	1½	3.02	36.1	2	0	.21	159.6	.14	1A, 1A	<.001	53.6	53.6	408	456	516	574	630
212	1,2,3	-	D, B, A	36.7	166	1	2.75	35.2	4	0	.20	153	.06	1,3	.000	52.0	50.2	370	450	506	584	649
213	2,3	2	D, B, A	34.5	162	1½	2.46	34.3	6	0	.44	137	.21	-,1	.001	48.5	45.3	357	429	503	584	639
214	2,3	2	D, B, A	32.6	170	1½	2.70	35.1	5	-5	.15	137	.13	-,1	.001	45.0	438	346	434	520	590	640
215	2,3	-	D, B, C	36.6	200	1	3.22	36.7	5	0	.18	161	<.1	1,1	.006	54.0	52.6	433	482	522	571	640

223	1,2	-	E,C	38.7	166	8/ 1	2.99	36.0	-	0	.20	162.2	<.15	1,1	-	-	54.6	352	434	506	598	640
224	1,2,3	2	E,C	37.1	164	1	3.95	39.0	16	0	.20	159	.10	1A,1A	.001	54.0	57.8	369	444	547	640	700
225	2,3	2	E,C	36.8	174	2	2.64	34.9	0	-10	.09	154	.08	1B,1B	.001	49.4	48.0	382	437	492	580	640
226	2	2	E,C,G	38.7	154	1	2.35	33.9	16	0	.16	150.8	.09	0,0	.000	51.1	52.7	330	389	495	594	639
227	3	-	E,C,G	37.3	170	1	3.06	36.2	14	0	.28	158	.09	0,0	.000	53.3	54.0	363	440	521	603	644
228	3(W)	-	E,C,G	40.0	152	1	2.28	33.6	-4	-15	.13	155.7	.07	0,0	.000	53.1	53.2	344	408	482	565	626
229	2,3	2	E,G,C,F,D	34.2	178	2	2.62	34.8	5	0	.46	140	.20	-,1	.001	49.0	44.7	380	444	504	595	660
Average (50 samples)				36.3	-	-	2.74	35.2	-	-	0.275	147.6	0.113	-	0.001	50.5	50.4	367	432	507	590	646
Minimum				17.6	126	1	2.09	33.0	-12	-40	0.03	62.0	0.01	-	0.000	43	41.0	318	372	461	556	626
Maximum				44.8	240	4½	4.39	40.4	22	0	.70	175.6	.34	-	.006	60	64.2	472	506	552	648	700

Southern region: District D

207	3	-	D	39.7	166	1	2.47	34.3	-5	-10	0.053	157	0.06	-,0	0.000	50.5	50.2	364	415	468	574	648
208	3	2	D	36.6	170	1½	2.83	35.5	-	0	.144	-	.04	-,1	.000	52.0	49.4	354	430	502	580	642
209	1,2,3	-	D	37.5	170	1	2.69	35.0	2	0	.05	150.4	.08	0,0	.000	50.0	50.2	368	429	495	569	627
210	2,3	-	D	31.5	240	1	4.38	40.4	6	-5	.13	151.2	.16	1A,1A	<.001	47.2	44.2	470	504	537	593	674
211	1,2,3	-	D,B.A	37.5	188	1½	3.02	36.1	2	0	.21	159.6	.14	1A,1A	<.001	53.6	53.6	408	456	516	574	630
212	1,2,3	-	D,8,A	36.7	166	1	2.75	35.2	4	0	.20	153	.06	1,3	.000	52.0	50.2	370	450	506	584	649
213	2,3	2	D,B,A	34.5	162	1½	2.46	34.3	6	0	.44	137	.21	-,1	.001	48.5	45.3	357	429	503	584	639
214	2,3	2	D,8,A	32.6	170	1½	2.70	35.1	5	-5	.15	137	.13	-,1	.001	45.0	43.8	346	434	520	590	640
215	2,3	-	D,8,C	36.6	200	1	3.22	36.7	5	0	.18	161	<.1	1,1	.006	54.0	52.6	433	482	522	571	640
216	2	-	D,E	35.7	172	2	2.99	36.0	5	-10	.24	156	.08	1,1	.001	50.0	49.5	390	446	514	608	674
217	3	-	D,E,G	34.5	180	2	2.99	36.0	5	-10	.30	145	.08	1,1	.001	46.0	46.3	388	450	510	610	676
218	2,3	-	D,G,E	38.4	168	1	2.59	34.7	5	0	.059	158	.07	-,0	.000	52.5	53.8	367	428	506	583	634
219	2,3	2	D,G,E	36.7	162	1½	2.68	35.0	5	0	.084	149	.09	-,0	.000	46.9	49.0	358	422	498	586	653
220	3	-	D,G,J	37.1	168	1	2.98	36.0	14	0	.47	157.0	.09	0,1	.000	54.6	53.4	361	429	520	623	674
171	2,3	2	A,B,D,C,E	32.7	154	2½	2.57	34.6	2	-5	.50	131.2	.29	1,1	<.001	50	42.5	343	423	510	594	640
172	4	2	A,8,D,C,E	17.6	240	4½	4.39	40.4	-	-15	.27	62.0	7/ .14	1,1	<.001	7/ 25	7/ 14.6	472	506	552	648	700
180	1,2,3	-	8,A,D,G	37.2	160	1	2.68	35.0	4	0	.20	155.8	.22	1,1	.002	54	53.0	346	414	516	594	638
181	1,2,3	-	8,C,A,D	37.7	162	1½	2.62	34.8	0	-10	.185	153	.02	-,1	.000	50.9	50.5	368	425	495	586	631
182	2	2	B,C,D	32.5	162	1	3.35	37.2	10	0	.55	140	.13	0,1	.000	47.8	43.2	351	436	517	597	657
183	3	-	8,C,D	37.1	172	1	2.75	35.2	10	0	.31	156	.045	0,0	.000	51.2	52.0	380	442	511	589	669
184	2,3	2	8,C,D,A	35.6	140	2	2.30	33.7	5	-5	.40	138	.14	1,1	.001	46	46.6	327	410	498	588	630
185	2,3,4	-	B,D,A	34.0	170	1½	2.75	35.2	0	0	.40	145	.06	1,3	.001	46.0	45.0	370	410	508	586	648
186	3	-	8,D,A	35.7	160	1½	3.00	36.0	5	0	.49	128.0	.11	-,1	.001	48.0	48.0	366	430	506	580	636
187	3	2	8,D,A,C	35.4	156	2	2.52	34.5	0	< 0	.41	141	.01	-,1	.000	47.7	46.2	356	421	498	588	638
229	2,3	2	E,G,C,F,D	34.2	178	2	2.62	34.8	5	0	.46	140	.20	-,1	.001	49.0	44.7	380	444	504	595	660
236	2	-	G,D	39.1	164	1	2.50	34.4	-2	-5	.38	160	.10	1,1	.000	58	56.5	364	418	512	576	628
237	2	-	G,D	37.2	172	1	3.00	36.0	6	0	.42	160	.12	1,1	.000	56	53.5	370	440	520	584	636
238	2	-	G,D	34.2	180	1	3.90	38.8	8	0	.78	150	.14	1,1	.001	50	56.2	388	480	580	632	674
242	3	-	G,E.F,D	39.1	186	8/ 10	3.15	36.5	10	0	.15	169	.07	-,1	.002	-	55.8	398	440	508	616	673
Average (29 samples)				35.3	-	-	2.93	35.8	-	-	0.297	146.4	0.109	-	0.001	50.3	49.5	376	439	512	592	650
Minimum				17.6	140	1	2.30	33.7	-5	-15	0.05	62.0	0.01	-	0.000	45.0	42.5	327	410	468	569	627
Maximum				39.7	240	4½	4.39	40.4	14	0	.78	169	.29	-	.006	58	56.5	472	506	580	648	700

1/ Classes 1, 2, 3, and 4 of diesel fuel oils are described in the text. (S) or (W) indicates the fuel is recommended for use only during the summer or winter season, respectively.

2/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of distribution of the fuel. Fuels listed above the lines separating items 206 and 211 are generally sold in greatest volume in the Eastern region. The fuels listed above the line separating items 220 and 171 are generally sold in greatest volume in the Southern region. The fuels listed below the lines are generally sold in lesser volumes in the two respective regions than in some other region.

3/ Viscosities reported in one term were converted to equivalent figures in the other, where possible, as explained in the text, page 9. The Saybolt viscosity given in the average is the equivalent of the kinematic viscosity average.

4/ Some of the determinations were made by the Conradson method, ASTM D189-52, and the data were converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

5/ Corrosion test results are given separately for the two temperatures by number according to ASTM D130-53T or ASTM D130-54T.

6/ Distillation figures have been converted, where necessary, to temperatures at 760 mm. Hg according to table 1 in ASTM D86-52.

7/ Not within specification of fuels for this grade, figure not included in average.

8/ Color by Saybolt chromometer, ASTM D156-52.

TABLE 6. --Analyses of grade 2-D diesel fuel oils with maximum pour point 0° F., 1955 (Cont.)

Item	Marketed as: Diesel fuel oil, class 1/	Marketed as: Burner fuel oil A.S.T.M. D396 Grade	Distributed in districts 2/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D93 ° F.	Color Union A.S.T.M. D155 No.	Viscosity at 100° F. 3/ Kinematic A.S.T.M. D445 cs.	Viscosity at 100° F. 3/ Saybolt A.S.T.M. D88 Sec.	Cloud test A.S.T.M. D97 ° F.	Pour point A.S.T.M. D97 ° F.	Sulfur content A.S.T.M. D129 percent	Aniline point A.S.T.M. D611 ° F.	Carbon Res. 4/ A.S.T.M. D524 on 10% Res., %	Corrosion A.S.T.M. D130 5/ 3 hours at 122° F. and 212° F.	Ash A.S.T.M. D482 percent	Cetane number A.S.T.M. D613	Calculated Cetane Index A.S.T.M. D975	Distillation 6/ A.S.T.M. D158 Temperature ° F. IBP	10 % recovered	50 % recovered	90 % recovered	End point
Central region: Districts E, F, and G																						
221	3	-	E	37.6	146	1½	2.47	34.3	4	0	0.71	146.8	0.115	1A, 1A	0.000	53.5	51.5	340	418	502	584	633
222	2,3	2	E	38.2	7/ 155	1	3.30	37.0	-	0	.31	167	.15	1,1	.000	58	55.6	341	445	519	609	661
223	1,2	-	E,C	38.7	166	8/ 1	2.99	36.0	-	0	.20	162.2	<.15	1,1	-	-	54.6	352	434	506	598	640
224	1,2,3	2	E,C	37.1	164	1	3.95	39.0	16	0	.20	159	.10	1A, 1A	.001	54.0	57.8	369	444	547	640	700
225	2,3	2	E,C	36.8	174	2	2.64	34.9	0	-10	.09	154	.08	1B, 1B	.001	49.4	48.0	382	437	492	580	640
226	2	2	E,C,G	38.7	154	1	2.35	33.9	16	0	.16	150.8	.09	0,0	.000	51.1	52.7	330	389	495	594	639
227	3	-	E,C,G	37.3	170	1	3.06	36.2	14	0	.28	158	.09	0,0	.000	53.3	54.0	363	440	521	603	644
228	3(W)	-	E,C,G	40.0	152	1	2.28	33.6	-4	-15	.13	155.7	.07	0,0	.000	53.1	53.2	344	408	482	565	626
229	2,3	2	E,G,C,F,D	34.2	178	2	2.62	34.8	5	0	.46	140	.20	-,1	.001	49.0	44.7	380	444	504	595	660
230	1,2,3	-	F,G	38.5	158	1	2.62	34.8	-	-15	.14	158	.04	1,1	.01	55	51.0	380	422	488	594	643
231	1,2,3	-	F,H,E	38.1	150	1	2.87	35.6	-	-15	-	-	.06	1A, 1A	Trace	-	51.3	346	398	494	570	626
232	1,2,3	2	G	35.4	7/ 136	1	2.38	34.0	-	-5	.237	140	.14	1A, 1A	-	46.6	45.3	359	428	492	577	633
233	4	-	G	28.6	180	1	5.51	44	-50	-85	.7	137	.11	4,-	.001	40	40.2	425	488	550	630	770
234	-	-	G	38.9	162	(Red)	2.10	33.0	1	-5	.12	164.1	.08	1,1	.000	-	58.0	355	455	524	596	652
235	-	-	G	36.5	172	1½	2.38	34.0	-1	-5	.26	151.2	.128	1,1	.000	-	49.2	348	433	501	587	648
236	2	-	G,D	39.1	164	1	2.50	34.4	-2	-5	.38	160	.10	1,1	.000	58	56.5	364	418	512	576	628
237	2	-	G,D	37.2	172	1	3.00	36.0	6	0	.42	160	.12	1,1	.000	56	53.5	370	440	520	584	636
238	2	-	G,D	34.2	180	1	3.90	38.8	8	0	.78	150	.14	1,1	.001	50	56.2	388	480	580	632	674
239	2,3	-	G,E	33.7	156	1½	2.84	35.5	2	0	.202	141	.112	0,0	.001	44.8	46.5	370	454	522	594	640
240	2,3	2	G,E,F	37.7	158	1½	2.24	33.5	8	-10	.20	141	.17	1,-	.001	52	48.4	330	399	482	568	631
241	1,2	1,2	G,E,F	35.8	166	1	3.14	36.5	6	0	.18	154.8	.08	1A, 1A	.000	50.5	53.3	358	433	537	602	630
242	3	-	G,E,F,D	39.1	186	8/ 10	3.15	36.5	10	0	.15	169	.07	-,1	.002	-	55.8	398	440	508	616	673
243	2,3	-	G,F	39.0	185	1	2.77	35.3	2	-5	.17	161	.1	1,1	.001	-	54.5	405	446	502	576	626
244	2,3	-	G,F,E	37.2	178	1	2.93	35.8	-15	-15	.21	-	.09	-,1A	.000	-	50.8	400	440	504	604	650
245	2	2	G,F,E	37.6	158	1	2.83	35.5	15	0	.68	158.0	.07	0,0	.001	50.8	53.5	346	418	514	610	670
246	3	-	G,F,E	40.6	164	1	2.69	35.0	15	0	.37	169.5	.046	0,0	.000	55.8	59.4	354	426	510	610	670
247	2,3	-	G,F,E	37.0	164	1	2.44	34.2	-2	-5	.119	152	.094	0,0	.000	50.7	51.2	362	430	508	584	626
248	1,2	-	G,F,E,J	37.8	195	1½	3.00	36.0	10	0	.12	162.5	.12	1,1	.002	-	55.2	412	472	522	577	628
249	3	-	G,I	33.1	175	2½	3.12	36.4	-	0	.442	-	-	-,-	-	44.0	42.7	406	452	506	575	649
171	2,3	2	A,B,D,C,E	32.7	154	2½	2.57	34.6	2	-5	.50	131.2	.29	1,1	<.001	50	42.5	343	423	510	594	640
172	4	2	A,B,D,C,E	17.6	240	4½	4.39	40.4	-	-15	.27	62.0	9/ 1.14	1,1	<.001	9/ 25	9/ 14.6	472	506	552	648	700
180	1,2,3	-	B,A,D,G	37.2	160	1	2.68	35.0	4	0	.20	155.8	.22	1,1	.002	54	53.0	346	414	516	594	638
203	1,2,3	2	C,E	38.1	150	8/ 12	3.16	36.5	2	-5	.284	158	.097	1A, 1A	.00	56.0	58.5	352	448	532	599	649
204	3	2	C,E	29.5	206	1	3.24	36.8	7	0	.21	120	.180	0,0	.001	9/ 39.0	9/ 39.2	460	486	530	590	648

205	1,2,3	2	C,E	34.5	154	1	3.05	36.2	8	0	.17	148	.100	0,0	.001	47.0	50.8	340	432	540	598	664
206	1,2,3	2	C,E	31.9	174	1	3.27	36.9	7	0	.27	138.5	.120	0,0	.001	44.0	44.8	372	464	536	594	652
216	2	-	D,E	35.7	172	2	2.99	36.0	5	-10	.24	156	.08	1,1	.001	50.0	49.5	390	446	514	608	674
217	3	-	D,E,G	34.5	180	2	2.99	36.0	5	-10	.30	145	.08	1,1	.001	46.0	46.3	388	450	510	610	676
218	2,3	-	D,G,E	38.4	168	1	2.59	34.7	5	0	.059	158	.07	-,0	.000	52.5	53.8	367	428	506	583	634
219	2,3	2	D,G,E	36.7	162	1½	2.68	35.0	5	0	.084	149	.09	-,0	.000	46.9	49.0	358	422	498	586	653
220	3	-	D,G,J	37.1	168	1	2.98	36.0	14	0	.47	157.0	.09	0,1	.000	54.6	53.4	361	429	520	623	674
259	3	-	I,K,H,F	38.8	158	1	2.75	35.2	-5	-10	.47	152	.082	0,0	.000	52.0	51.3	370	412	486	592	644
261	2,3	2	J,G	37.8	170	1	3.3	37.0	5	-10	.352	153	.08	0,-	.005	-	52.8	385	443	507	596	652
Average (43 samples)				36.1	-	-	2.95	35.9	-	-	0.293	150.2	0.110	-	0.001	50.9	51.5	372	438	514	596	652
Minimum				17.6	146	1	2.10	33.0	-50	-85	0.059	62.0	0.04	-	0.000	40	40.2	330	389	482	565	626
Maximum				40.6	240	4½	5.51	44	16	0	.78	169.5	.29	-	.005	58	59.4	472	506	580	648	770
Rocky Mountain region: Districts H, I, J, and K																						
250	2,3(S)	2	H	36.6	188	1	2.90	35.7	-10	-5	0.703	156	0.002	0,0	< 0.001	53.2	52.8	396	448	523	588	633
251	2,3	-	H,I,K,L	37.0	168	1	2.68	35.0	-5	-15	.35	146.2	.07	1,1	.000	50.5	49.9	376	430	500	588	650
252	2,3(W)	-	H,I,K,L	35.3	178	1	3.30	37.0	0	-10	.40	147.4	.08	1,1	.000	51.0	51.0	375	458	530	602	662
253	1,2,3	-	H,L	38.8	156	1½	2.13	33.1	-22	-30	10/ .461	145	.08	1,1	.006	51.4	48.8	352	409	471	565	630
254	2,3	-	H,L	36.5	166	3½	2.74	35.2	2	0	10/ .608	145	.08	1,1	.003	46.8	49.0	364	425	500	615	704
255	3(W)	-	I	36.6	168	8/12	3.16	37.0	6	0	.721	155.5	.11	1,1	.001	-	52.5	382	450	521	601	646
256	3	-	I	33.1	180	8/ 22	2.74	35.0	4	0	.744	137.0	.12	1,1	.001	-	42.3	397	449	504	599	654
257	1,2,3	2	I,H	34.9	7/ 174	2	2.44	34.2	-	-25	.500	136.4	.12	1A,-	.001	46.8	42.0	405	435	479	571	631
258	1,2,3	-	I,H	38.2	191	2	2.50	34.4	-8	-20	.148	152.6	.08	-,1A	.001	52.5	50.3	382	419	487	576	630
259	3	-	I,K,H,F	38.8	158	1	2.75	35.2	-5	-10	.47	152	.082	0,0	.000	52.0	51.3	370	412	486	592	644
260	2,3	-	J	36.0	198	1	3.30	37.0	10	-10	10/ .30	153.4	.10	-,1	.00	51	51.7	422	464	525	612	662
261	2,3	2	J,G	37.8	170	1	3.3	37.0	5	-10	.352	153	.08	0,-	.005	-	52.8	385	443	507	596	652
262	2,3	2	K,L	22.9	-	1	3.12	36.4	-5	-10	.97	70	.20	-,0	.004	9/ 23.6	9/ 20.0	427	457	480	529	630
263	2,3(W)	2	K,L,M	37.3	158	8/ 1	2.59	34.7	2	-10	.37	149.0	.09	-,1	.00	49.0	49.8	357	434	495	573	644
220	3	-	D,G,J	37.1	168	1	2.98	36.0	14	0	.47	157.0	.09	0,1	.000	54.6	53.4	361	429	520	623	674
231	1,2,3	-	F,H,E	38.1	150	1	2.87	35.6	-	-15	-	-	.06	1A,1A	Trace	-	51.3	346	398	494	570	626
248	1,2	-	G,F,E,J	37.8	195	1½	3.00	36.0	10	0	.12	162.5	.12	1,1	.002	-	55.2	412	472	522	577	628
249	3	-	G,I	33.1	175	2½	3.12	36.4	-	0	.442	-	-	-	-	44.0	42.7	406	452	506	575	649
267	2(W)	-	M,L,K	35.0	154	3	2.65	34.9	-	-10	.28	-	-	-	-	45	44.6	380	434	493	585	662
Average (19 samples)				35.8	-	-	2.86	35.6	-	-	0.467	144.9	0.092	-	0.002	49.8	49.5	384	438	502	586	648
Minimum				22.9	150	1	2.13	33.1	-22	-30	0.12	70	0.002	-	0.000	45	42.0	346	398	471	529	626
Maximum				38.8	198	3½	3.30	37.0	14	0	.97	162.5	.20	-	.006	54.6	55.2	427	472	530	623	704

1/ Classes 1, 2, 3, and 4 of diesel fuel oils are described in the text. (S) or (W) indicates the fuel is recommended for use only during the summer or winter season, respectively.

2/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of distribution of the fuel. Fuels listed above the lines separating items 249 and 171 are generally sold in greatest volume in the Central region. The fuels listed above the line separating items 263 and 220 are generally sold in greatest volumes in the Rocky Mountain region. The fuels listed below the lines are generally sold in lesser volumes in the two respective regions than in some other region.

3/ Viscosities reported in one term were converted to equivalent figures in the other, where possible, as explained in the text, page 9. The Saybolt viscosity given in the average is the equivalent of the kinematic viscosity average.

4/ Some of the determinations were made by the Conradson method, ASTM D189-52, and the data were converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

5/ Corrosion test results are shown by number according to ASTM D130-53T or ASTM D130-54T.

6/ Distillation figures have been converted, where necessary, to temperatures at 760 mm. Hg according to table 1 in ASTM D86-52.

7/ Flash point by Tag closed tester, ASTM D56-52. 8/ Color by Saybolt chromometer, ASTM D156-52.

9/ Not within specification of fuels for this grade, figure not included in average.

10/ Determined by lamp method.

TABLE 6.--Analyses of grade 2-D diesel fuel oils with maximum pour point 0° F., 1955 (Cont.)

Item	Marketed as: Diesel fuel oil, class 1/	Marketed as: Burner fuel oil A.S.T.M. D396 Grade	Distributed in districts 2/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D93 ° F.	Color Union A.S.T.M. D155 No.	Viscosity at 100° F. 3/ Kinematic A.S.T.M. D445 cs.	Viscosity at 100° F. 3/ Saybolt A.S.T.M. D88 Sec.	Cloud test A.S.T.M. D97 ° F.	Pour point A.S.T.M. D97 ° F.	Sulfur content A.S.T.M. D129 percent	Aniline point A.S.T.M. D611 ° F.	Carbon Res. 4/ A.S.T.M. D524 on 10% Res., %	Corrosion A.S.T.M. D130 5/ 3 hours at 122° F. and 212° F.	Ash A.S.T.M. D482 percent	Cetane number A.S.T.M. D613	Calculated Cetane Index A.S.T.M. D975	Distillation 6/ A.S.T.M. D158 Temperature ° F. IBP	% recovered 10	50	90	End point
Western region: Districts L, M, and N																						
264	2,3,4(W)	2	L,M,N	32.1	166	4½	3.56	37.8	-	0	0.72	140	0.18	-	-	44.0	45.3	360	464	536	603	648
265	3	-	L,M,N	33.5	170	3	2.68	35.0	-	-10	.46	-	.12	-,1	-	42	41.0	350	438	490	584	675
266	2,3,4(W)	2	L,N,M	31.8	170	3½	3.46	37.5	2	0	.44	139	.08	-,1	0.00	43.5	43.8	368	449	530	604	670
267	2(W)	-	M,L,K	35.0	154	3	2.65	34.9	-	-10	.28	-	-	-	-	45	44.6	380	434	493	585	662
268	2	-	N	33.5	210	2½	3.6	38.0	10	0	.60	148	.10	1,1	.004	45	46.0	420	468	522	624	668
269	2,3(S)	2	N	33.9	164	7/ 2	3.02	36.1	10	0	.31	140.5	.10	-,1	.00	43.0	44.0	370	433	504	605	675
270	2,3(W)	2	N	33.5	160	7/ 3	3.08	36.3	5	-5	.31	140	.10	-,1	.00	43.0	43.8	380	432	508	605	675
271	2	-	N 8/	30.7	200	7/ 4	3.95	39.0	-6	0	.95	137	.06	-	.00	42.0	42.7	410	470	538	612	676
272	2,3,4(W)	2	N,L	32.3	176	7/ 4	3.62	38.0	10	0	.74	142	.11	-,1	.00	45.0	46.7	380	468	542	610	658
273	3	-	N,L	32.6	160	2	3.47	38.0	10	-5	.58	139.5	.10	1,1	< .001	41	45.4	366	444	530	626	672
274	2	2	N,M,L	32.9	168	2½	3.38	37.0	10	-5	.56	143.5	.10	1,1	< .001	43	46.6	376	450	534	620	670
275	2,3	-	N,M,L	36.4	190	2½	2.68	35.0	5	0	.48	148.3	.13	1,1	< .001	47	47.0	403	435	490	592	663
251	2,3	-	H,I,K,L	37.0	168	1	2.68	35.0	-5	-15	.35	146.2	.07	1,1	.000	50.5	49.9	376	430	500	588	650
252	2,3(W)	-	H,I,K,L	35.3	178	1	3.30	37.0	0	-10	.40	147.4	.08	1,1	.000	51.0	51.0	375	458	530	602	662
253	1,2,3	-	H,L	38.8	156	1½	2.13	33.1	-22	-30	9/ .46	145	.08	1,1	.006	51.4	48.8	352	409	471	565	630
254	2,3	-	H,L	36.5	166	3½	2.74	35.2	2	0	9/ .60	145	.08	1,1	.003	46.8	49.0	364	425	500	615	704
262	2,3	2	K,L	22.9	-	1	3.12	36.4	-5	-10	.97	70	.20	-,0	.004	10/ 23.6	10/ 20.0	427	457	480	529	630
263	2,3(W)	2	K,L,M	37.3	158	7/ 1	2.59	34.7	2	-10	.37	149.0	.09	-,1	.00	49.0	49.8	357	434	495	573	644
Average (18 samples)				33.7	-	-	3.10	36.4	-	-	0.533	138.8	0.105	-	0.001	45.4	46.2	379	444	511	597	663
Minimum				22.9	154	1	2.13	33.1	-22	-30	0.28	70	0.06	-	0.000	41	41.0	350	409	471	529	630
Maximum				38.8	210	4½	3.95	39.0	10	0	.97	149.0	.20	-	.006	51.4	51.0	427	470	542	626	704

1/ Classes 1, 2, 3, and 4 of diesel fuel oils are described in the text. (S) or (W) indicates the fuel is recommended for use only during the summer or winter season, respectively.

2/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of distribution of the fuel. Fuels listed above the line separating items 275 and 251 are generally sold in greatest volume in the Western region. The fuels listed below the line are generally sold in lesser volume in this region than in some other region.

3/ Viscosities reported in one term were converted to equivalent figures in the other, where possible, as explained in the text, page 9. The Saybolt viscosity given in the average is the equivalent of the kinematic viscosity average.

4/ Some of the determinations were made by the Conradson method, ASTM D189-52, and the data were converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

5/ Corrosion test results are given by number according to ASTM D130-53T or ASTM D130-54T.

6/ Distillation figures have been converted, where necessary, to temperatures at 760 mm. Hg according to table 1 in ASTM D86-52.

7/ Color by Saybolt chromameter, ASTM D156-52.

8/ Sold at large marine terminals only.

9/ Determined by lamp method, ASTM D90-50T.

10/ Not within specification of fuels for this grade, figure not included in average.

TABLE 7. — Analyses of grade 2-D diesel fuel oils with minimum pour point 5° F., 1955

Item	Marketed as: Diesel fuel oil, class 1/	Marketed as: Burner fuel oil A.S.T.M. D396 Grade	Distributed in districts 2/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D93 ° F.	Color Union A.S.T.M. D155 No.	Viscosity at 100° F. 3/ Kinematic A.S.T.M. D445 cs.	Viscosity at 100° F. 3/ Saybolt A.S.T.M. D88 Sec.	Cloud test A.S.T.M. D97 ° F.	Pour point A.S.T.M. D97 ° F.	Sulfur content A.S.T.M. D129 percent	Aniline point A.S.T.M. D611 ° F.	Carbon Res. 4/ A.S.T.M. D524 on 10% Res., %	Corrosion A.S.T.M. D130 5/ 3 hours at 122° F. and 212° F.	Ash A.S.T.M. D482 percent	Cetane number A.S.T.M. D613	Calculated Cetane Index A.S.T.M. D975	Distillation 6/ A.S.T.M. D158 Temperature ° F. IBP	% recovered 10	50	90	End point
Eastern region: Districts A, B, and C																						
276	2,4	2	A,B	33.7	170	1½	2.80	35.4	12	5	0.11	147.2	0.11	-,0	-	48	44.6	362	438	510	583	640
277	3	-	B	31.7	178	2	2.89	35.7	15	5	.16	136.4	.18	1,1	>0.001	43.0	41.6	388	463	517	593	653
278	2	2	C	42.6	180	1	2.96	35.9	20	20	.1	177.8	-	-	-	-	62.9	380	420	506	650	706
279	1,2,3	2	C	35.7	200	1	2.99	36.0	20	20	.10	157.3	.14	1,1	.001	56	51.6	444	484	528	590	638
280	4	2	C,E	28.2	210	4½	3.57	37.8	26	10	.31	126.8	.32	0,0	.001	7/ 39	7/ 39.8	433	488	553	622	652
Average (5 samples)				34.4	-	-	3.04	36.2	-	-	0.156	149.1	0.188	-	0.001	49.0	50.2	401	459	523	608	658
Minimum				28.2	170	1	2.80	35.4	12	5	0.10	126.8	0.11	-	<0.001	43.0	41.6	362	420	506	583	638
Maximum				42.6	210	4½	3.57	37.8	26	20	.31	177.8	.32	-	.001	56	62.9	444	488	553	650	706

Southern region: District D

281	4	-	D	30.9	186	(Green)	4.58	41.0	-	10	0.16	152.8	8/ 0.67	1,1	7/ 0.030	44	46.0	9/ 334	450	558	670	808
282	2,3	-	D,E	36.9	188	1	3.29	37.0	5	5	.05	165	.10	-,1	.000	55	53.6	389	474	524	578	632
283	2,3	-	G,D	37.3	190	(Red)	3.30	37.0	-	15	10/ .096	165	.054	1,1	.000	60.0	56.7	395	485	538	594	644
Average (3 samples)				35.0	-	-	3.72	38.3	-	-	0.102	160.9	0.077	-	0.000	53.0	52.1	373	470	540	614	695
Minimum				30.9	186	1	3.29	37.0	5	5	0.05	152.8	0.054	-	0.000	44	46.0	334	450	524	578	632
Maximum				37.3	190	-	4.58	41.0	-	15	.16	165	.10	-	-	60.0	56.7	395	485	558	670	808

Central region: Districts E, F, and G

283	2,3	-	G,D	37.3	190	(Red)	3.30	37.0	-	15	10/ 0.096	165	0.054	1,1	0.000	60.0	56.7	395	485	538	594	644
280	4	2	C,E	28.2	210	4½	3.57	37.8	26	10	.31	126.8	.32	0,0	0.001	7/ 39	7/ 39.8	433	488	553	622	652
282	2,3	-	D,E	36.9	188	1	3.29	37.0	5	5	.05	165	.10	-,1	.000	55	53.6	389	474	524	578	632
288	1,2,3(S)	-	J,G,I	40.1	200	(Amber)	2.77	35.3	8	5	.120	166	.08	-,1	.00	-	56.3	434	458	498	520	631
Average (4 samples)				35.6	-	-	3.23	36.8	-	-	0.144	155.7	0.139	-	0.000	57.5	55.5	413	476	528	579	640
Minimum				28.2	188	1	2.77	35.3	5	5	0.05	126.8	0.054	-	0.000	55	53.6	389	458	498	520	631
Maximum				40.1	210	4½	3.57	37.8	26	15	.31	166	.32	-	.001	60.0	56.7	434	488	553	622	652

Rocky Mountain region: Districts H, I, J, and K

284	2	2	H	34.9	218	1	3.74	38.4	20	15	0.850	167	0.035	0,0	<0.001	55.4	53.1	433	502	549	596	635
285	2	-	H	34.0	184	1	3.62	38.0	15	5	.65	150.2	.08	1,1	.000	51.5	51.9	392	482	554	618	668
286	2,3(S)	-	H,I,K,L	33.8	200	1	3.95	39.0	15	5	.42	149.5	.08	1,1	.000	51.5	50.8	390	480	550	612	665
287	3	-	J	30.6	200	1½	3.49	37.6	40	10	10/ .40	136.2	.13	-,1	.00	42	43.2	457	503	543	653	699
288	1,2,3(S)	-	J,G,I	40.1	200	(Amber)	2.77	35.3	8	5	.120	166	.08	-,1	.00	-	56.3	434	458	498	520	631
289	3	-	K,L	32.7	198	1	3.36	37.2	5	5	.62	146	.08	-,0	.002	46.2	47.2	417	500	540	587	631
290	2,3(S)	2	K,L,M	32.0	196	11/ 1	4.05	39.3	18	15	.70	154.5	.09	-,1	.00	47.0	48.2	409	500	558	619	680
292	2(W)	2	M,L,K	33.4	198	2	3.85	38.7	-	10	.33	154	-	-	.000	44	49.2	434	489	544	625	704
293	2(S)	2	M,N,L,K	34.6	184	2	3.52	37.7	-	15	.58	155	-	-	.000	49	50.0	388	466	533	631	720
Average (9 samples)				34.0	-	-	3.59	37.9	-	-	0.519	153.2	0.082	-	0.000	48.3	50.0	418	487	541	607	670
Minimum				30.6	184	1	2.77	35.3	5	5	0.120	136.2	0.035	-	0.000	42	43.2	388	458	498	520	631
Maximum				40.1	218	2	4.05	39.3	40	15	.850	167	.13	-	.002	55.4	56.3	457	503	558	653	720

Western region: Districts L, M, and N

291	2,3,4(S)	2	L,N,M	32.0	170	3½	3.49	37.6	6	10	0.44	141	0.08	-,1	0.00	43.5	43.8	380	452	528	608	675
292	2(W)	2	M,L,K	33.4	198	2	3.85	38.7	-	10	.33	154	-	-	.000	44	49.2	434	489	544	625	704
293	2(S)	2	M,N,L,K	34.6	184	2	3.52	37.7	-	15	.58	155	-	-	.000	49	50.0	388	466	533	631	720
294	2	2	N	32.0	230	2	4.3	40.0	10	5	.65	155	.10	1,1	.004	48	48.5	434	494	560	644	682
295	2	-	N	33.5	200	1½	3.62	38.0	-	5	.38	151	.13	-,1	.000	47.0	49.0	419	484	542	609	664
296	2,3,4(S)	2	N,L	32.5	188	11/ 4	3.95	39.0	8	5	.79	145	.08	-,1	.00	45.5	47.7	392	470	546	621	674
297	2,3	2	N,L,M	32.5	182	2½	3.8	38.5	10	5	.50	146	.12	-,1	.001	42.0	43.5	398	447	519	631	703
298	2,3	2	N,L,M	32.3	182	2½	3.61	38.0	15	5	.91	141	.15	-,1	.001	43.0	46.0	402	466	538	632	701
286	2,3(S)	-	H,I,K,L	33.8	200	1	3.95	39.0	15	5	.42	149.5	.08	1,1	.000	51.5	50.8	390	480	550	612	665
289	3	-	K,L	32.7	198	1	3.36	37.2	5	5	.62	146	.08	-,0	.002	46.2	47.2	417	500	540	587	631
290	2,3(S)	2	K,L,M	32.0	196	11/ 1	4.05	39.3	18	15	.70	154.5	.09	-,1	.00	47.0	48.2	409	500	558	619	680
Average (11 samples)				32.8	-	-	3.77	38.5	-	-	0.575	148.9	0.101	-	0.001	46.1	47.6	406	477	542	620	682
Minimum				32.0	170	1	3.36	37.2	5	5	0.33	141	0.08	-	0.000	42.0	43.5	380	447	519	587	631
Maximum				34.6	230	3½	4.3	40.0	18	15	.91	155	.15	-	.004	51.5	50.8	434	500	560	644	720

1/ Classes 1,2,3, and 4 of diesel fuel oils are described in the text. (S) or (W) indicates the fuel is recommended for use only during the summer or winter season, respectively.

2/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of distribution of the fuel. Fuels listed above the lines separating items 282 and 283 in the Southern region, items 283 and 280 in the Central region, items 290 and 292 in the Rocky Mountain region, and items 298 and 286 in the Western region are generally sold in greatest volumes in those respective regions. The fuels listed below the lines are generally sold in lesser volumes in the respective regions than in some other regions.

3/ Viscosities reported in one term were converted to equivalent figures in the other, where possible, as explained in the text, page 9. The Saybolt viscosity given in the average is the equivalent of the kinematic viscosity average.

4/ Same of the determinations were made by the Conradson method, ASTM D189-52, and the data were converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.

5/ Corrosion test results are given separately for the two temperatures by number according to ASTM D130-53T or ASTM D130-54T.

6/ Distillation figures have been converted, where necessary, to temperatures at 760 mm HG according to table 1 in ASTM D86-52.

7/ Not within specification of fuels for this grade, figure not included in average.

8/ On 100 percent sample, figure not included in average.

9/ Distillation temperatures are equivalent values at 760 mm. Hg converted from temperatures at reduced pressure according to the chart (Fig. 5) in the report by Beal, E.S.L., and Docksey, P., A Wide Range Boiling-Point Conversion Chart for Hydrocarbons and Petroleum Products: Jour. Inst. Petrol. Technol., Vol. 21, 1935, pp. 860-870. Also figure 25 (p. 1588) Science of Petroleum, Vol. 2, Oxford University Press, 1938.

10/ Determined by lamp method, ASTM D1266.

11/ Color by Saybolt chromometer, ASTM D156-49.

TABLE 8.--Analyses of grade 4-D diesel-fuel oils, 1955

Item	Marketed as: Diesel fuel oil, class 1/	Marketed as: Burner fuel oil A.S.T.M. D396 Grade	Distributed in districts 2/	Gravity A.S.T.M. D287 ° A.P.I.	Flash point A.S.T.M. D93 ° F.	Color Union A.S.T.M. D155 No.	Viscosity at 100° F. 3/ Kinematic A.S.T.M. D445 cs.	Viscosity at 100° F. 3/ Saybolt A.S.T.M. D88 Sec.	Cloud test A.S.T.M. D97 ° F.	Pour point A.S.T.M. D97 ° F.	Sulfur content A.S.T.M. D129 percent	Aniline point A.S.T.M. D611 ° F.	Carbon residue Ramsbottom 4/ A.S.T.M. D524 On 10% residue, %	Carbon residue Ramsbottom 4/ A.S.T.M. D524 On 100% sample, %	Corrosion A.S.T.M. D130 5/ 3 hours at 122° F. and 212° F.	Ash A.S.T.M. D482 percent	Cetane number A.S.T.M. D613	Calculated Cetane Index A.S.T.M. D975	Distillation 6/ A.S.T.M. D158 Temperature ° F. IBP	% recovered 10	% recovered 50	% recovered 90	End point
Eastern region: Districts A, B, and C																							
299	4	-	B 7/	26.2	230	-	35.3	165.1	-	35	0.39	182.9	-	1.64	0,0	0.003	-	53.8	457	549	695	-	-
300	4	4	B	22.6	196	(Green)	8/ 5.20	8/ 43.0	-	-15	.53	117.2	1.80	.45	1,1	.004	34	8/ 26.7	9/ 370	458	534	720	842
301	4	-	B	24.6	212	-	9.73	58.0	-	-10	1.09	-	-	.10	-	.000	38.0	-	-	-	-	-	-
302	3, 4	4	C	33.0	205	3	8.86	55.0	34	20	.30	179	.26	-	1,-	.0	-	60.6	415	544	632	748	> 760
303	3, 4(W)	4	C	33.3	160	3	7.09	49.1	24	0	.33	173	.24	-	1,-	.0	-	60.5	351	447	626	716	718
304	4	4	C, E	24.2	180	(Black)	18.72	92.4	-	15	.820	-	-	3.72	1,-	.082	-	-	-	-	-	-	-
Average (6 samples)				27.3	-	-	15.94	81.1	-	-	0.577	163.0	0.77	1.48	-	0.015	-	58.3	398	500	622	728	773
Minimum				22.6	160	-	7.09	49.1	24	-15	0.30	117.2	0.24	0.10	-	0.000	34	53.8	351	447	534	716	718
Maximum				33.3	230	-	35.3	165.1	34	35	1.09	182.9	1.80	3.72	-	.082	38.0	60.6	457	549	695	748	842
Southern region: District B																							
305	4	-	D	28.6	195	-	6.60	47.5	-	20	0.55	-	-	0.59	-	0.000	42.0	-	-	-	-	-	-
306	3, 4	-	D	26.8	230	2½	5.83	45.0	20	10	.30	156	.12	.01	1,3	.001	40.0	44.6	410	500	610	690	>760
307	4	-	D 7/	26.5	255	(Dark)	34.0	159.0	-	45	.32	10/ 164.5	-	1.66	1,1	.003	45	54.3	438	538	694	-	-
308	4	-	D	31.8	190	(Black)	6.29	46.5	-	15	.74	162	-	.65	-	.005	-	-	-	-	-	-	-
309	4	-	D	31.6	178	(Black)	6.14	46.0	-	-5	.17	153	-	.69	-	.005	-	49.2	358	460	570	706	(11)
Average (5 samples)				29.1	-	-	11.77	65.2	-	-	0.416	158.9	-	0.72	-	0.003	42.3	49.4	402	499	625	-	-
Minimum				26.5	178	-	5.83	45.0	-	-5	0.17	153	-	0.01	-	0.000	40.0	44.6	358	460	570	690	-
Maximum				31.8	255	-	34.0	159.0	-	45	.74	164.5	-	1.66	-	.005	45	54.3	438	538	694	706	>760
Central region: Districts E, F, and G																							
304	4	4	C, E	24.2	180	(Black)	18.72	92.4	-	15	0.820	-	-	3.72	1,-	0.082	-	-	-	-	-	-	-
Rocky Mountain region: Districts H, I, J, and K (no representation)																							
Western region: Districts L, M, and N																							
310	4	-	N 7/	17.4	174	-	56.9	264.0	-	10	1.79	118	-	5.2	-	0.02	-	-	366	458	658	-	-
311	4	-	N 7/	17.4	194	(Black)	63.8	295.8	-	-35	.97	123	-	6.1	-	.03	-	-	9/ (12)	463	602	-	>760
312	4	-	N	27.1	190	(Black)	7.37	50.0	-	10	1.18	145	-	1.06	-	.005	39.5	38.0	400	472	555	730	(11)
Average (3 samples)				20.6	-	-	42.7	198.5	-	-	1.31	128.7	-	4.12	-	0.018	-	-	383	464	605	-	-
Minimum				17.4	174	-	7.37	50.0	-	-35	0.97	118	-	1.06	-	0.005	-	-	366	458	555	-	-
Maximum				27.1	194	-	63.8	295.8	-	10	1.79	145	-	6.1	-	.03	-	-	400	472	658	-	-

1/ Classes 3 and 4 of diesel fuel oils are described in the text.
2/ District letters refer to the areas in which the fuels are sold (see fig. 1). In each item the arrangement of district letters indicates in decreasing order the relative volumes of distribution of the fuel. The fuels listed above the lines are generally sold in greatest volume in the respective regions. The fuel listed below the line--item 304 in the Central region--is sold in lesser volume in that region than in the Eastern region.
3/ Viscosities reported in one term were converted to equivalent figures in the other, where possible, as explained in the text, page 9. The Saybolt viscosity given in the average is the equivalent of the kinematic viscosity average.
4/ Some of the determinations were made by the Conradson method, ASTM D189-52, and the data were converted to Ramsbottom values using table 1 and figure 4 in the appendix of the Conradson method.
5/ Corrosion test results are given separately for the two temperatures by number according to ASTM D130-53T or ASTM D130-54T.
6/ Distillation figures have been converted, where necessary, to temperatures at 760 mm Hg according to table 1 in ASTM D86-52.
7/ Sold at large marine terminals only.
8/ Not within specification of fuels for this grade, figure not included in average.
9/ Distillation temperatures are equivalent values at 760 mm. Hg converted from temperatures at reduced pressure according to the chart (fig. 5) in the report by Beale, E. S. L., and Docksey, P., A Wide Range Boiling-Point Conversion Chart for Hydrocarbons and Petroleum Products: Jour. Inst. Petrol. Technol., Vol. 21, 1935, pp. 860-870. Also figure 25 (p. 1,588) Science of Petroleum, Vol. 2, Oxford University Press, 1938.
10/ Mixed aniline point. 11/ Cracking.
12/ Initial boiling point not reported, temperature at 5 percent 450° F.

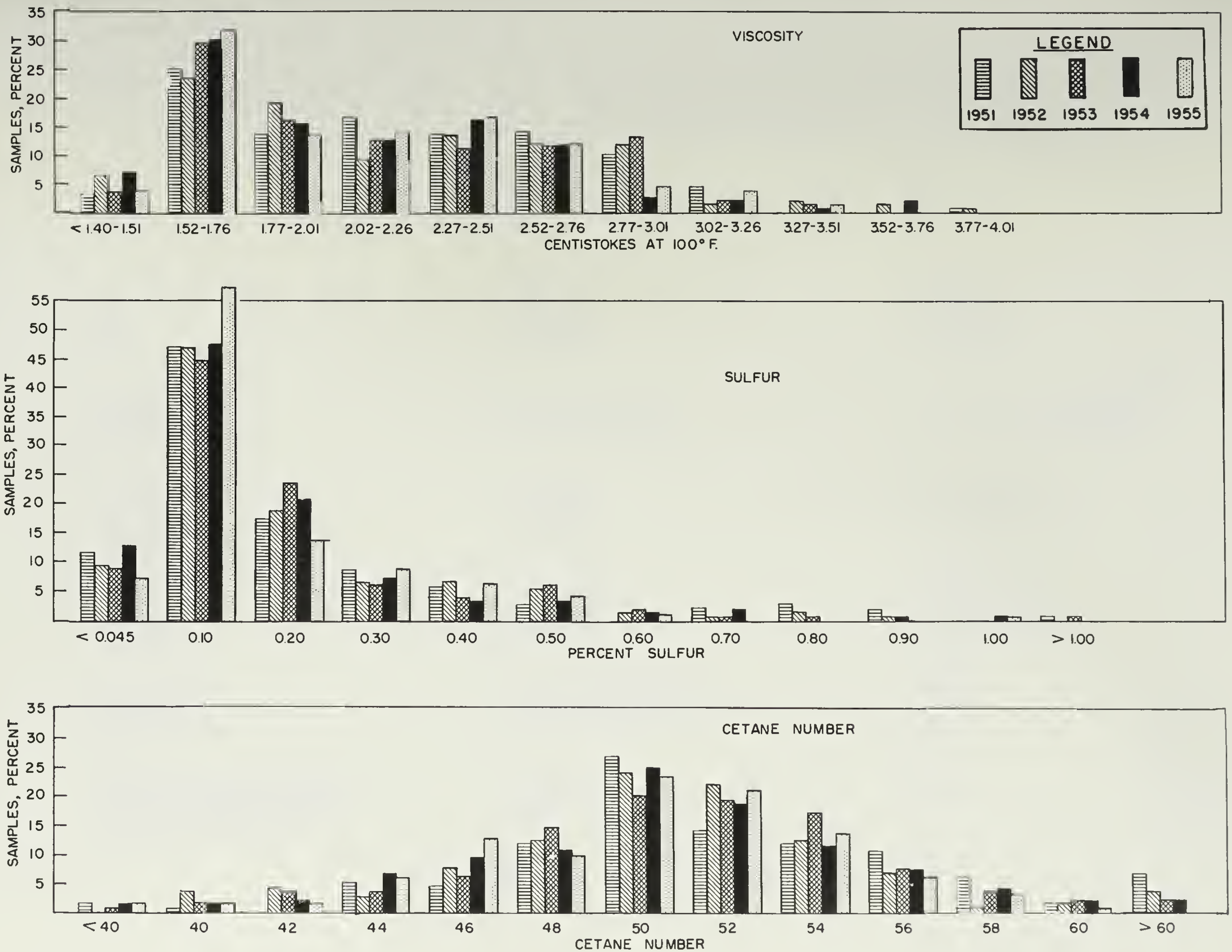

Figure 2. - Charts of selected properties of diesel fuels showing frequency distributions of samples, 1951-1955, grade 1-D.

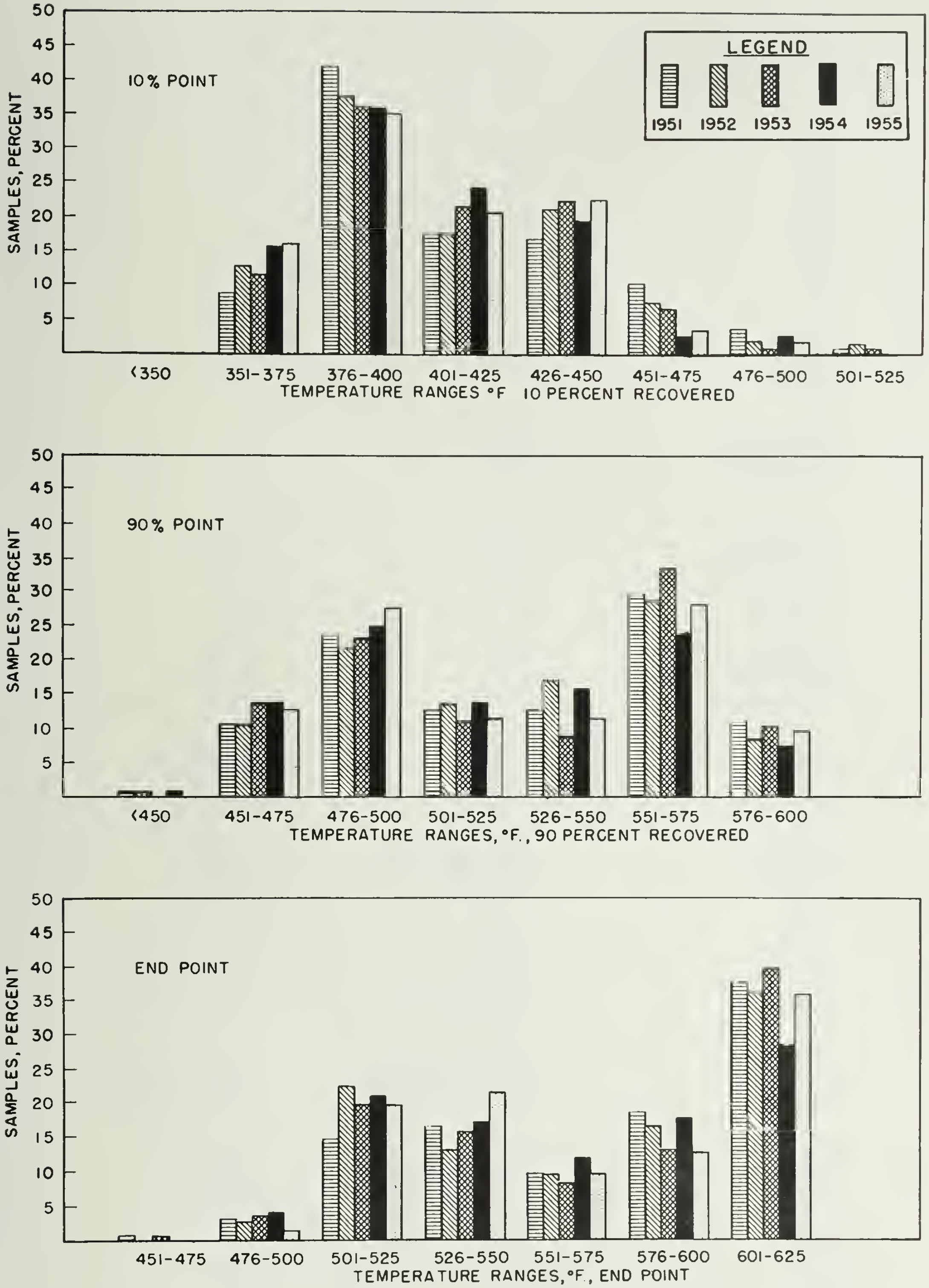

Figure 3.- Charts of selected properties of diesel fuels showing frequency distributions of samples, 1951-1955, grade 1-D.

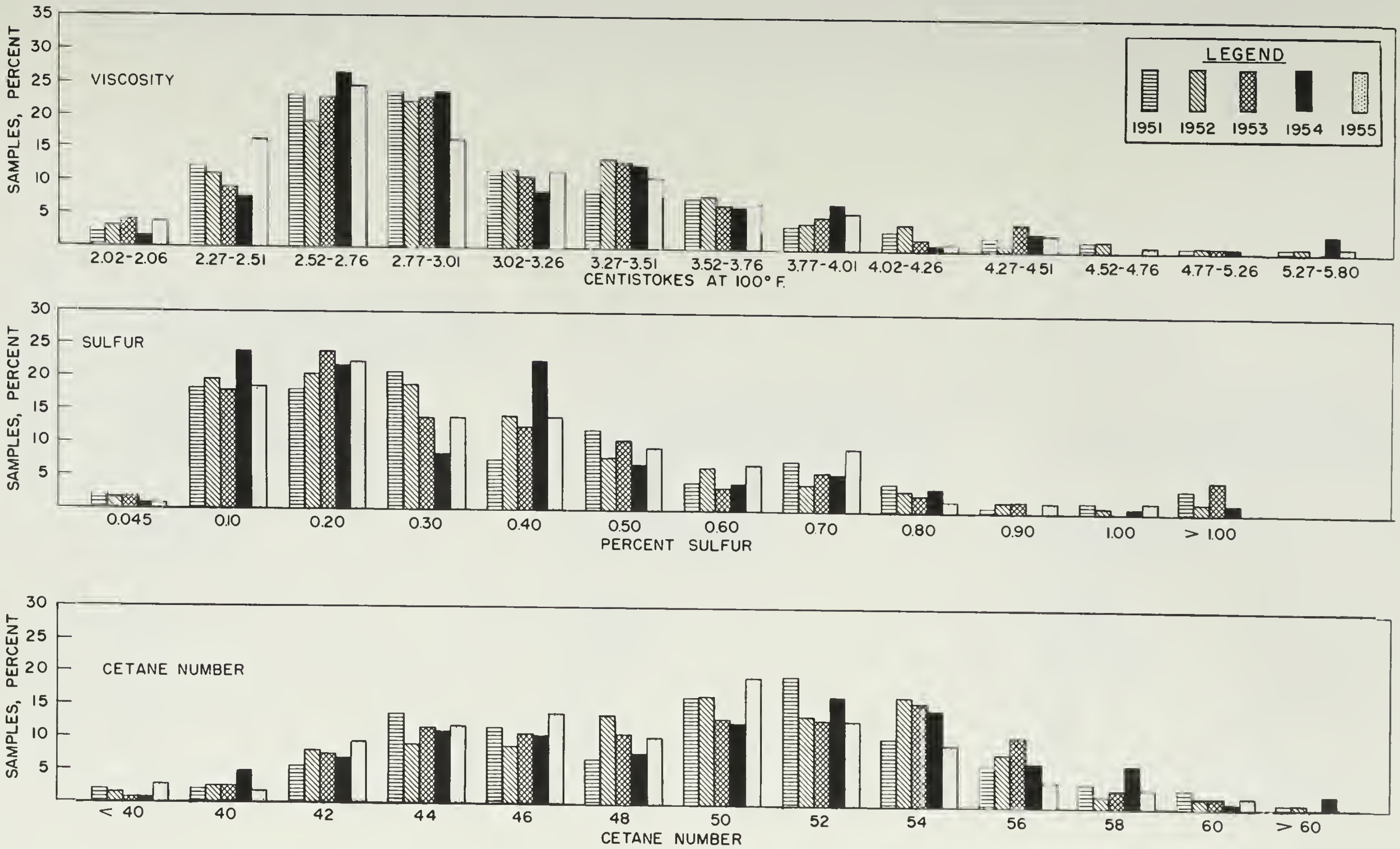

Figure 4. - Chorts of selected properties of diesel fuels showing frequency distributions of somples, 1951-1955, grode 2-D.

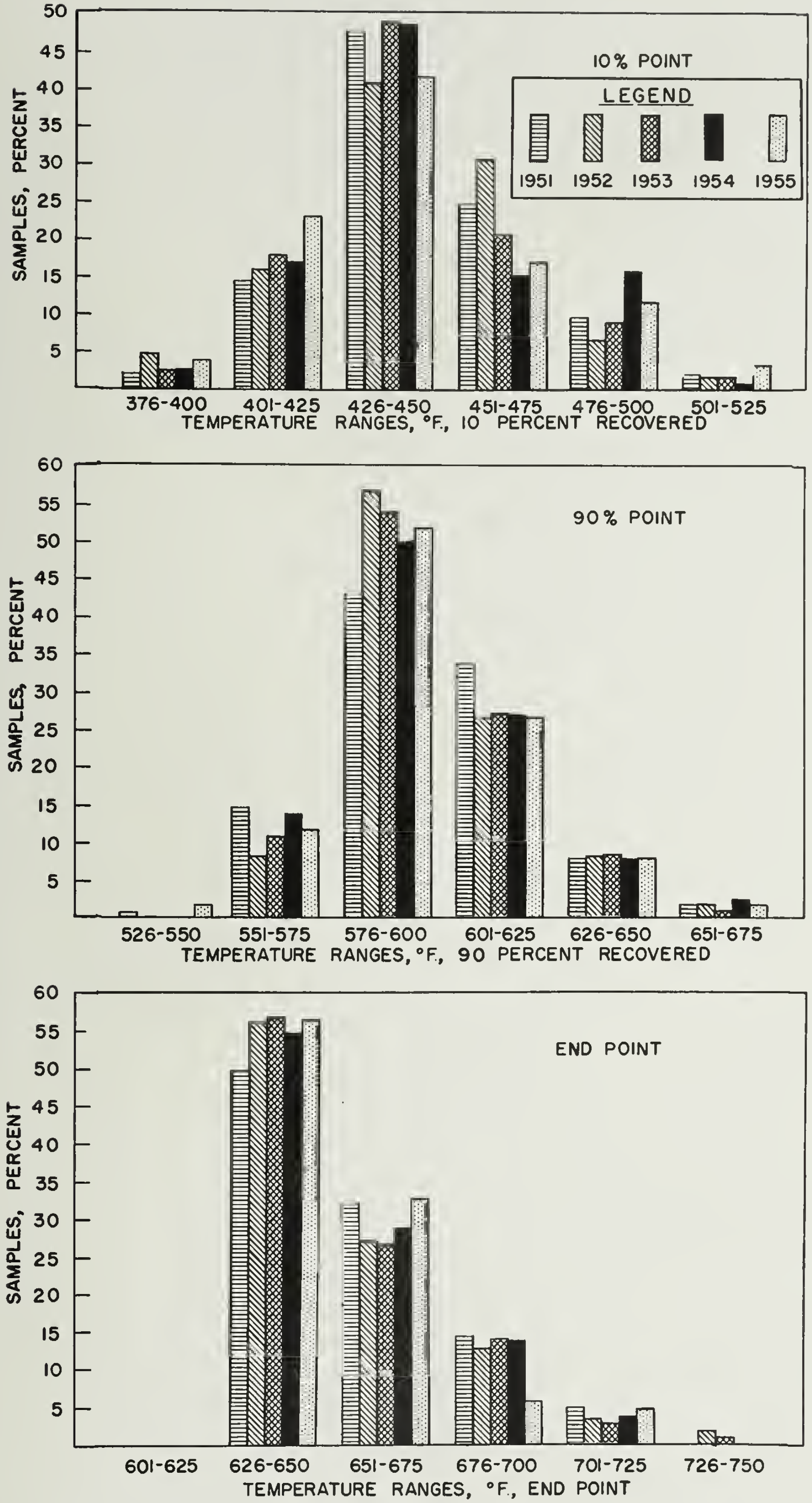

Figure 5. - Charts of selected properties of diesel fuels showing frequency distributions of samples, 1951-1955, grade 2-D.

Bureau of Mines
Information Circular 7738

LIMESTONE AND DOLOMITE

BY OLIVER BOWLES

United States Department of the Interior — March 1956

LIMESTONE AND DOLOMITE

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. . . . **Information Circular 7738**

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
Thos. H. Miller, Acting Director

March 1956

LIMESTONE AND DOLOMITE

by

Oliver Bowles 1/

CONTENTS

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ILLUSTRATIONS

INTRODUCTION

Limestone, including dolomite, is the most widely used of all rocks - nearly 300 million tons annually in the United States alone. It occurs in some form in every State and is produced in thousands of localities. Because of its attractiveness, substantiality, and durability it is employed extensively as a building stone. In crushed and broken form it is used for concrete aggregate and railroad ballast and in highway construction, metallurgy, agriculture, and a host of chemical and industrial processes.

This paper proposes to furnish general information on the origin and occurrence of limestone and dolomite, chief production centers, major uses, and methods of quarrying and preparing stone for market. Footnote references will guide the reader to sources of more complete information.

COMPOSITION AND ORIGIN

The essential constituent of limestone is calcium carbonate ($CaCO_3$). If the magnesium carbonate content is small the rock is known as a "high-calcium" limestone. If 10 percent or more of magnesium carbonate is present it is called "magnesian" or "dolomitic" limestone. When the content of magnesium carbonate approaches 45 percent it is known as dolomite, which is the double carbonate of calcium and magnesium ($CaCO_3.MgCO_3$). The term "limestone" in its broader sense includes dolomite.

Limestones are named on the basis of their prevailing impurities, provided the impurities are present in considerable quantities. Thus siliceous or cherty limestones contain considerable quantities of silica; argillaceous limestones contain clay; and ferruginous limestones contain iron oxides, which make the rock reddish or yellowish. Carbonaceous or bituminous limestones contain peat or other organic materials, which may make the rock dark gray or black.

Limestones consist chiefly of calcareous shells of organisms that inhabit oceans and lakes. Countless generations of them have lived and died, and their shells have accumulated, sometimes to great depths, on sea and lake floors. Such supplies are supplemented by chemically precipitated calcium and magnesium carbonates. Some deposits consist almost entirely of the carbonates and become the sources of pure, high-grade limestones. In other places sand, clay, iron oxide, or other detrital material may be mixed or interbedded with the carbonates in larger or smaller quantities. During later ages beds of sand or clay may have been superimposed, and the resulting earth pressure gradually consolidated the carbonates and other minerals into firm rock. Through long geologic ages of earth adjustment some of the rocks so formed may have been elevated to occupy land areas where they can be exploited for commercial use.

In most instances the original shells have been so comminuted by wave action or reduced by pressure and earth movement that the shell structure has been almost

completely destroyed. In some deposits, however, the shells may remain more or less intact. Such rocks may consist predominantly of shells of one kind, and the limestone may be named accordingly, for instance, coral, crinoid, or coquina limestones. Chalk is a fine-grained white, friable limestone composed largely of minute shells of foraminifera. Oystershell beds may be regarded as present-day unconsolidated limestones that may in future geologic ages become beds of firm, hard rock.

Another series of names is applied to limestones according to their physical character. Common compact is the most widespread type, it consists of a fine-grained, dense, homogeneous aggregate varying in color from light gray to almost black. Lithographic is a very fine-grained crystalline variety, usually drab or yellowish. Oölitic limestone is made up of small, rounded grains of lime carbonate with a concentrically laminated structure.

Two varieties of limestone, travertine and Mexican onyx, consist of calcium carbonate that has been deposited from solution. The first is a product of chemical precipitation from hot springs. It is deposited in successive layers; and as chemical composition and conditions of deposition may vary during the process, a banded structure commonly results. The rock is characterized by numerous irregular cavities. The second type, Mexican or cave onyx, is deposited from cold-water solutions, usually in limestone caves; it is to be distinguished from true onyx, which consists of silica. As Mexican onyx can be polished it is classed with marbles rather than with limestones and is commonly designated onyx marble.

BRANCHES OF THE INDUSTRY

The limestone industry is divided into two distinct branches - dimension stone and crushed stone. The outstanding distinction is that dimension stone is prepared in the form of rectangular blocks and as cut stone in specified sizes and shapes. Rough building stone may consist of more or less irregular blocks, but usually at least one good face is demanded. On the other hand, crushed and broken stone consists of irregular fragments.

The two branches have little in common. In quarrying dimension stone explosives are employed very sparingly because the integrity of blocks must be preserved, but heavy charges of explosive are used in a crushed-stone quarry to reduce the rock to fragments. All subsequent methods and equipment for preparing the products for market are dissimilar, and marketing problems are different also.

The crushed- and pulverized-limestone industries are subdivided into three main branches; one includes stone sold or used in its natural state except for crushing, grinding and sizing, and the other two involve calcining processes used in manufacturing cement and lime - the two important primary products manufactured in conjunction with quarrying. To indicate the magnitude of the limestone industry, table 1, showing statistics for a recent 3-year period, has been included.

TABLE 1. - Limestone sold or used in the United States, 1950-52, in short tons

	1950	1951	1952
Dimension stone	808,000	807,000	787,000
Crushed and broken stone..	254,452,000	285,468,000	296,919,000
Total	255,260,000	286,275,000	297,706,000

DIMENSION STONE

Requisite Qualities

Although numerous limestone deposits occur throughout the country, only a few consist of rock that will satisfy the exacting requirements of dimension stone. Deposits with irregular or closely spaced joints are unsuitable because large blocks free from cracks or lines of weakness are demanded. Limestones are variable in physical properties, such as texture, porosity, hardness, strength, and color, and upon these properties depends their adaptability as dimension stone. Only those limestones that are compact, easily workable, uniformly textured, and attractively colored merit consideration for such use.

Purity is not regarded as an essential property of a building limestone, although some types of impurities may impair its quality or workability: Silica may make a stone difficult to work, and iron sulfides, pyrite or marcasite in a building stone may result in iron stains on weathered surfaces.

Uses

Dimension limestone is used principally for building. It may be employed for entire exteriors or in conjunction with brick or other building materials. It is used also for columns and for interior structural and decorative purposes. Thin slabs are used for flagging.

Structural Units

Cut stone consists of blocks that are cut to specified dimensions and surface tooled. Nowadays ashlar is included with cut stone. The term "ashlar" is applied to the smaller rectangular blocks. Even-course ashlar consists of blocks of uniform height for each course, although succeeding courses may be of thicker or thinner blocks. Random ashlar consists of blocks of several sizes that may be fitted together to make a wall having unequally spaced joints. Small blocks with untooled surfaces are sometimes included with ashlar, but during recent years they have usually been included with the class known as house-stone veneer, which consists of rough-surfaced blocks or strips broken in irregular lengths and used extensively as a facing or veneer on residences or other structures.

Rough building stone consists of rock-faced masses of various shapes and sizes. Stonemasons build them into walls having irregular joints. They are widely used in residential construction for chimneys, basements, or entire walls and also to some extent for public buildings, bridges, fences, and the more ornamental types of retaining walls.

Rubble is the crudest form of building stone. The term is generally applied to irregular fragments having at least one good face. Such stone was once in ordinary use for basement walls, retaining walls, or similar types of construction for which concrete is now generally used. The use of rubble has declined greatly since the portland-cement era began.

Flagstones consist of thin slabs that may have irregular outlines or may be sawed into rectangular blocks.

Location of Deposits

The following locations are the most important as current sources of commercial building limestone.

Alabama

Limestone occurring in a belt about 20 miles long in Franklin County is known as the Bangor formation of Palaeozoic age. Gray to buff commercial stone lies in beds 20 to 25 feet thick. It is oölitic in texture (resembling fish roe) and consists of about 97 percent $CaCO_3$ and a small percentage of magnesium carbonate. The largest quarry is near Rockwood, where the stone is fabricated in a large mill. It has been sold widely for many years.

Indiana

Indiana is the chief source of building limestone in the United States; it furnishes about 60 percent of the total. The Salem oölitic limestone, of Lower Carboniferous age, occurs in a massive bed 25 to about 100 feet thick extending from near New Albany on the Ohio River northwest to a point north of Greencastle, about 125 miles. Active quarrying is confined chiefly to the Bedford-Bloomington area in Lawrence and Monroe Counties. The commercial stone ranges in composition from 97 to 98 percent $CaCO_3$. The availability of the rock in large, sound blocks and its easy workability, uniform texture, and durability have encouraged extensive development. The stone is shipped to virtually all parts of the country, and some is exported. Several large quarries and more than a dozen fully equipped mills operate in the area.

Kansas

A buff to ligh-cream limestone is quarried near Silverdale, Cowley County. It is similar in texture and physical properties to Indiana limestone.

Minnesota

Virtually all of the limestones of Minnesota are dolomitic. The Onesta dolomite of Ordovician age furnishes most of the building limestone. It has been quarried for many years at Mankato, Blue Earth County, Kasota, Le Sueur County, and Winona, Winona County. The stone at Mankato is available in large blocks well adapted for bridges and other heavy masonry. The general color tone is buff; the bottom ledge is bluish, but when exposed it slowly turns buff by oxidation of iron. The Kasota stone has been recrystallized to such an extent that it is sometimes classed as marble. The yellow and pink varieties are popular for interior trim and decoration. The gray to white Winona stone is quarried high on the Mississippi River bluffs. Some beds are porous and are marketed as travertine. The magnesium content is high enough to class it as a dolomite.

Missouri

Stone quarried at Carthage, Jasper County, and Phenix, Greene County, is sold chiefly as marble, but some of it is classed as limestone. Rough construction stone and rubble are produced at Perryville, Perry County, St. Charles, St. Charles County, and various other locations.

Pennsylvania

Considerable quantities of rough building stone and rubble are produced at various points, particularly in southeastern counties.

Texas

At Cedar Park, Williamson County, a ledge about 30 feet thick provides a pale-buff to cream oölitic limestone which is quarried for building stone. Certain beds contain large fossils and are porous, resembling travertine. At Lueders, Jones County, a deposit of thin-bedded, light-gray and variegated limestone, harder than the Cedar Park stone, is quarried for building purposes.

Wisconsin

A thin-bedded, gray dolomite is quarried near Lannon, Waukesha County and is used widely as building stone and flagging. It contains about 51 percent $CaCO_3$, 41 percent $MgCO_3$, and 6 percent silica.

Prospecting and Development

Development should not be begun on a deposit without reasonable assurance of an adequate supply of limestone suitable for dimension-stone uses. Generally it is deemed unwise to expend large sums in establishing quarries and finishing mills unless a reserve for at least 20 years' operation is assured. The extent and quality of the deposit should be investigated as far as possible from outcrops. The spacing and arrangement of joints are important because these natural partings govern the maximum size of blocks obtainable. A deposit should be capable of furnishing rectangular blocks several feet in length and width and 1 to several feet thick free from cracks or incipient seams. The arrangement and spacing of joints and the soundness and uniformity of the rock can best be judged from exposures. Where the overburden is thin, stripping or trenching may be desirable for wider visual inspection.

Core drilling is usually desirable for determining the extent and quality of a deposit. The cores will show the general quality and uniformity of the stone and the thickness of the beds.

Color, texture, and uniformity of a limestone are important. Representative samples should be submitted to architects and builders for comment because a favorable reaction from the building trades is essential to success.

Most deposits of limestone usable as dimension stone are approximately flat lying and of moderate thickness. Overburden is usually removed with power shovels or other earth-moving equipment. The hydraulic method may be employed advantageously where the surface contour is favorable, water abundant, and a disposal area available. The method is especially advantageous for washing clay from mud seams.

Quarrying

Making Primary Cuts

Channeling machines are generally used to make primary cuts for block separation. The cutting mechanism operates with a chopping action similar to that of a reciprocating drill and cuts a channel or narrow trench on one or both sides as the

machine travels back and forth on a track. The edge of the cutting tool is 1-7/8 to 2-1/8 inches wide and makes a channel about 2 or 2-1/4 inches wide.

In small quarries primary breaks may be made by discharging light charges of blasting powder in drill holes. This method is most successful in relatively thin bedded limestones having open bed seams.

Wire saws are used to some extent in Indiana as substitutes for channeling machines. The wire runs as a belt and cuts by abrasion. Sand is used as the cutting agent. Details of its use have been published (14).[2/]

Bed Lifting

Bed lifting is the term applied to the process of breaking the channeled blocks free from the quarry floor. This is a necessary process in the absence of open bed seams. In Indiana beds are lifted by driving wedges in a series of horizontal drill holes at the quarry floor. Masses of rock thus broken loose may be 50 or 60 feet long, 12 feet high, and 4 or more feet wide.

Block Subdivision

The large masses of stone that have been separated are first turned down with sheave and tackle before they are subdivided. Blocks of desired sizes are laid out with square and straightedge. Holes are drilled in line 6 to 8 inches deep and 12 to 18 inches apart. Fractures are made by the "plug-and-feather" method. The "feathers" consist of strips of iron that are flat on one side for contact with the wedge and curved on the other to fit the wall of the drill hole. Two are placed in a drill hole, and a plug - a steel wedge about 6 inches long - is driven between them. They are sledged lightly in succession until a fracture appears. Blocks are commonly 10 by 4 by 3 feet, and 10 by 4 by 4 feet. Figure 1 shows blocks that have been turned down ready for subdivision.

Hoisting

The blocks are hoisted generally with steel or wooden derricks of 30- to 50-ton capacity. Most of them are of the swinging-boom type.

Yard Operations

Storage and Transportation

Large storage capacity is essential, especially in cold climates where enough stone must be accumulated during the summer to supply winter mill demands. Outdoor storage may be maintained at the quarry or mill or at both places. The blocks may be piled and reclaimed by derricks with swinging booms or by overhead traveling cranes.

Scabbling

The term "scabbling" is applied to the process of trimming blocks of stone to desired dimensions and smooth surfaces. It is particularly important at quarries that ship limestone blocks to distant mills, because careful trimming reduces freight charges on waste.

2/ Underlined numbers in parentheses refer to items in the bibliography at the end of this report.

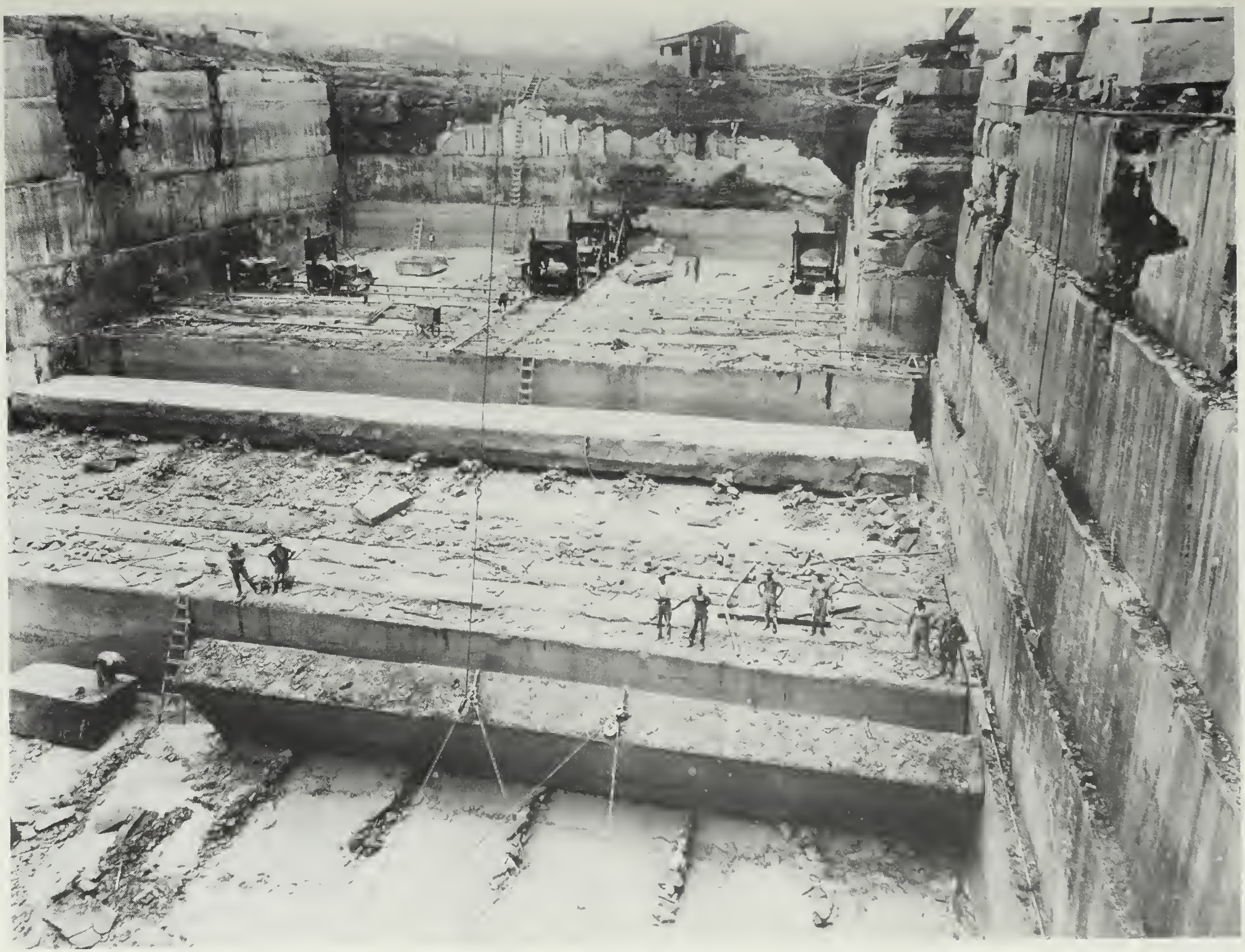

Figure 1. - Blocks of dimension limestone turned down ready for subdivision.
(Courtesy Building Stone Association of Indiana, Inc.)

Several methods are employed. Scabbling picks similar to ordinary double-pointed miners' picks are sometimes used, but sawing is generally more satisfactory and economical. Diamond-tooth drag saws or diamond-tooth circular saws may be employed. Scabbling planers are effective substitutes for saws. They consist of two sets of massive vertical blades that scrape off irregularities as the block is dragged between them. Wire saws are used also, enabling several blocks to be lined up and trimmed at the same time.

Milling

Drafting and Pattern Making

Before a cut-stone job can be begun, accurate detailed drawings must be made of every piece of stone to be used that differs from another in size or shape. Architects' drawings usually are insufficient because the stone must be fitted securely to the steel framework, and detailed data on the size and position of each steel member are necessary before the stoneworkers' shop drawings can be made. Patterns for molded and carved work are made of zinc or other soft metal. Sometimes paper patterns or stencils are used. For the more intricate carved work, plaster models are used.

After shop drawings are made draftsmen prepare a ticket for every block of stone on which is a drawing of the block with exact dimensions indicated. The ticket is numbered, and if a pattern is to be used its number also is shown. The man in charge of gang sawing first gets the ticket and cuts the block or slab. As the block passes to the planer, jointer, and all subsequent machines, the ticket goes with it, and each worker consults it before any work is begun. By this means workmanship is constantly verified, and few mistakes occur. Great skill and care are required, because one small error may ruin a block.

Block Handling

Mills are generally equipped with overhead traveling cranes. Commonly two cranes are used - a heavy one for placing blocks on saw beds and a lighter, more rapidly moving machine for handling smaller blocks and slabs.

Sawing

The first step in manufacture is to saw rough blocks to required dimensions. Gang saws are used almost exclusively for this purpose. They consist of a series of soft steel blades set in parallel positions in a frame that swings backward and forward. As the frame moves, actuated by a crank and connecting rod (pitman), the cutting blades lift toward the end of each stroke. This permits the sand abrasive to wash under them, promoting effective abrasive action. The blades may be spaced for thin slabs or thick blocks. An adjustable automatic gear feeds the gangs downward at any desired rate. An average cutting rate on standard mill blocks is about 6 inches an hour.

Another type, a straight steel blade set with diamond teeth, is used as a drag saw for making single cuts.

For making subsequent cuts, circular diamond saws are widely used. The blades are steel, one-fourth inch thick, with a series of square notches around the rim. Teeth mounted with diamonds are set in the notches and held in place with copper rivets. A stream of water cools the cutting edge and carries away the cuttings. The sawing rate is 3 to 15 inches a minute, depending upon the depth of the cut.

Planing

Planers are used for cutting stone blocks and slabs to smooth surfaces and desired thicknesses and also for cutting moldings and shaping curved designs. The frame that holds the cutting tool has lateral and vertical motion. The top and sides of a block may be planed simultaneously. A block of stone is carried beneath a planer on a traveling bed called a platen at a rate of 30 to 45 feet a minute, and the cutter scrapes a thin layer from the surface. Cutting tools are shaped to fit molding designs; that is, the tool is the reverse of the pattern.

A carborundum planer consists of two saws with a drum of smaller diameter between them. The saws trim the sides of the slab while the drum smooths the upper surface. The planer bed travels at a rate of only 20 to 30 inches a minute but finishes the job in 1 cut.

Turning and Fluting

In making columns the block of stone is first scabbled to cylindrical shape and then mounted in a lathe in which it rotates against a tool traveling slowly back and forth over the full length of the stone. The fluted columns also are made in a lathe. The flutes are drawn with pencil or crayon on the surface of the column; and the fluting tool, attached to the tool post of the lathe, travels back and forth while the column remains stationary. This process is continued until the line bounding the flutes is reached. When a flute is completed, the column is rotated with a hand bar, and the process is repeated in the new position. The ends are finished with pneumatic tools.

Cutting and Carving

Cutting usually is defined as straightline work and carving as curved work. Carving requires great skill, and most of it is done by experienced workers. Pneumatic tools are generally used, a heavy one for removing the larger fragments and smaller ones for completing designs. The hand chisel and mallet are still used for certain operations.

Finishing

Various types of surface finish are achieved by using different tools. A <u>tooled</u> surface, which is one covered with fine grooves in parallel lines, is made with a pneumatic or planer tool having fine teeth. A <u>bush-hammered</u> surface is rough and pitted, the hammer used having a face covered with small projections. A <u>4-cut</u> surface is made with a planer tool having 4 corrugations to the inch. A <u>shot-sawed</u> or <u>ripple</u> surface is deeply scored or grooved by using steel shot as abrasive for the gang saw. <u>Chat-sawed</u> is smoother than shot-sawed stone.

Physical and Chemical Properties

The physical properties and chemical composition of representative limestones are given in tables 2 and 3. The data have been compiled from reports of the National Bureau of Standards, State geological survey reports, and various reference and text books.

TABLE 2. - Physical properties of limestones

Source	Type	Compressive strength,[1] lb. per sq. in.	Transverse strength[1] (modulus of rupture), lb. per sq. in.	Specific gravity	Absorption, percent	Weight per cubic foot, lb.
Bedford, Ind.	Oölitic	4,000	900 to 1,600	2.17	3.6 to 5.5	135
Do...........	do.	4,000 to 7,000	1,510	2.28	4.0	142
Bloomington, Ind..	do.	4,000 to 5,700	900 to 1,600	2.17	7.0	136
Do...........	do.	5,700	1,355	2.42	5.1	150
Rockwood, Ala.....	do.	9,700	1,610	2.34	4.5	146
Silverdale, Kan...	do.	6,700	1,055	2.10	8.9	131
Mankato, Minn.....	Dolomitic (cream)	13,500	1,565	2.45	3.66	155
Kasota, Minn......	Dolomitic (pink)	21,320	1,995	2.53	3.4	158
Winona, Minn......	Travertine	17,000	955	2.53	2.8	158
Lueders, Tex......	Oölitic	8,900	1,120	2.22	6.5	139
Cedar Park, Tex...	do.	2,600	640	1.87	12.3	117
Lannon, Wis.......	Dolomitic	-	-	2.85	9.0	170

1/ Perpendicular to bedding.

TABLE 3. - Chemical composition of limestones

Source	Type	CaO	MgO	CO_2	Fe_2O_3	Al_2O_3	SO_3	Insol.
Rockwood, Ala.	Oölitic	54.70	0.72	43.13	0.32	0.28	0.05	-
Bedford, Ind.	do.	54.80	.72	43.30	.15	.55	.07	-
Bloomington, Ind.	do.	54.54	.59	42.90	.08	.68	.06	-
Mankato, Minn.	Dolomite	27.40	18.90	42.10	1.10	-	-	10.40
Kasota, Minn.	do.	27.76	15.40	38.72	-	-	-	13.18
Winona, Minn.	Travertine	30.80	19.70	45.70	.60	-	-	3.20

Specifications

Specifications have been established for stone (including limestone) to be used in Federal building projects. For exterior building stone the specifications are comprised in a 12-page pamphlet entitled "Stone Work," issued by General Services Administration, Public Buildings Service, dated March 1950. Copies may be obtained by addressing a request to Public Buildings Service, GSA, Washington 25, D. C. The specification indicates the physical and chemical properties required and covers the dimensions, design, surface finish, workmanship, and setting. For non-Government construction the architects or builders may prepare specifications, but more generally they use the specifications promulgated by the limestone-producing companies, with such modifications as may be mutually agreed upon.

Marketing

Dimension stone is sold by the cubic foot, and much of it commands a price high enough to give it a nationwide market. Two-thirds or more of all building limestone is sold as rough blocks or sawed slabs to mills in consuming centers, where it is fabricated chiefly for small or moderate-size buildings. The balance of the production is manufactured for specific projects, usually of large size, in mills operated

in conjuction with quarries or in independent mills. The smaller limestone quarries usually sell their stone to local builders and contractors.

CRUSHED AND BROKEN STONE

Production of crushed and broken limestone (excluding that used in making cement and lime) has experienced remarkable growth. In 1922 it reached 52,684,000 tons; in 1942, 142,025,000 tons; and in 1952, an alltime high of 216,468,000 tons. This fourfold increase in 30 years is due primarily to the rapid growth in highway and building construction and to wide expansion in the metallurgical, chemical, and processing industries for which limestone is an essential raw material. Limestone made up 72 percent of all crushed and broken stone sold in 1952.

Uses

Wide Range of Applications

For many of the uses of crushed limestone, physical properties are of primary importance; for others, chemical composition is a dominant requirement. Many limestones have the physical qualities that render them adaptable to virtually all of the uses for which any crushed stone may be employed, but limestone also has active chemical properties that make it not only useful but essential to many chemical and industrial processes. Limestone has the widest and most diversified uses of all varieties of stone.

Table 4 indicates the magnitude of the requirements for various uses of crushed and broken stone in 1951 and 1952. Corresponding figures for later years are given in the Stone chapters of the Minerals Yearbook published annually by the Bureau of Mines.

Uses for Which Physical Properties Are Most Important

Concrete Aggregate

A vast tonnage of limestone is used as aggregate for concrete in which form it is consumed chiefly in highway construction and in the building trades. Data on specifications are given later under Marketing.

Although consumers may differ in some respects as to the requisite qualities of stone for use as aggregate, generally it should consist of clean, hard, strong, durable, uncoated fragments free from injurious amounts of soft, friable, thin, elongated, or laminated pieces. Alkalies and organic matter are usually undesirable. Soluble sulfides are objectionable because they oxidize, and the sulfuric acid formed will attack calcareous materials that may be present and form gypsum, which expands during crystallization and disrupts concrete.

Various tests are made to ascertain the fitness of limestone. They formerly included the Deval abrasion test, the Dory hardness test, the Page impact test, and ordinary crushing-strength tests, but these tests have been almost universally supplanted by the Los Angeles abrasion test. For determining soundness the more important are the freezing and thawing, the sodium sulfate, and the magnesium sulfate tests. Each involves freezing or crystallization of a substance in the pores or cracks, which results in heavy interior strain. The resistance of the stone to disruption is a measure of its soundness.

TABLE 4. - Limestone, crushed and broken, sold or used in the United States, by principal uses, 1951-52

Use	1951 Short tons	1951 Value	1952 Short tons	1952 Value
Concrete and roadstone	112,717,000	$140,354,000	127,379,000	$163,581,000
Railroad ballast	9,085,000	9,575,000	8,827,000	9,390,000
Fluxing stone	39,930,000	45,622,000	34,909,000	41,119,000
Agriculture	19,401,000	31,052,000	21,152,000	34,464,000
Riprap	3,101,000	4,043,000	4,872,000	6,424,000
Alkali works	7,709,000	7,207,000	6,558,000	6,448,000
Calcium carbide	889,000	904,000	723,000	762,000
Coal-mine dusting	385,000	1,523,000	422,000	1,685,000
Filler	2,023,000	5,703,000	1,953,000	5,412,000
Filter beds	193,000	306,000	89,000	146,000
Glass factories	794,000	1,907,000	814,000	1,933,000
Limestone sand	800,000	962,000	1,698,000	2,158,000
Limestone whiting	710,000	6,702,000	762,000	7,165,000
Paper mills	446,000	943,000	360,000	821,000
Poultry grit	99,000	524,000	79,000	604,000
Refractory (dolomite)	1,112,000	1,520,000	708,000	1,048,000
Road base	1,485,000	1,310,000	1,371,000	1,245,000
Sugar factories	563,000	1,369,000	541,000	1,404,000
Other and unspecified	3,231,000	7,822,000	3,251,000	8,054,000
Total	204,673,000	$269,348,000	216,468,000	$293,863,000
Cement	64,284,000	(1)	64,305,000	(1)
Lime	16,511,000	(1)	16,146,000	(1)
Grand total (approximate)	285,468,000	(1)	296,919,000	(1)

1/ Data not available.

Much study is being devoted to proper sizing of aggregates and proper proportioning of the various sizes to obtain maximum strength and durability with a minimum of cement.

Road Stone

Stone of various sizes ranging from 3-1/2 inch to dust is used in road construction. The size gradations vary according to use. The principal types of application are waterbound macadam, graded aggregate base course, bituminous macadam, bituminous plant mixes, bituminous surface treatment, and portland-cement concrete. Detailed size gradations for each of the above uses are given in Simplified Practice Recommendation R 163-48, issued by the United States Department of Commerce.

The requisite qualities of road stone are similar to those of aggregate, except that resistance to abrasion is of primary importance. A soft stone disintegrates under traffic; and a laminated stone, even if fairly hard, breaks into flat or elongated pieces that may not compact solidly. Stone of low porosity is desirable; otherwise, water may penetrate and soften the structure of the road. Road stone should break into sharply angular, chunky fragments that, when properly graded for size, will interlock and press firmly into the surface of the road.

Various standard methods of testing, sampling, and mechanically analyzing road materials are given in the American Society for Testing Materials Standards.

Railroad Ballast

Large quantities of limestone are used by railroad companies for maintaining road beds. A minimum of 3/4 inch and a maximum of 2-1/2 inches (round openings) for ballast sizes has been widely used, but lately there has been a trend toward the use of smaller sizes. The requirements as to quality are generally the same as for aggregate and road stone.

Asphalt Filler

Limestone dust, approximately 80 percent of which will pass a 200-mesh screen, is used as a filler in road asphalt surface mixtures. Much of it is classed as a by-product at crushed-stone plants, although the preparation of asphalt filler is a substantial part of the business of some quarrying companies.

Riprap

Riprap consists of heavy, irregular blocks used chiefly for river and harbor work, such as spillways at dams, shore protection, and docks. It is a low-priced product and is usually procured from nearby quarries. Any type of dense, sound limestone may be used; there are no general specifications.

Coal-Mine Dusting

Operators of bituminous-coal mines employ fine, incombustible dusts for distribution throughout their mines as a means of preventing or checking coal-dust explosions. Limestone dust is particularly satisfactory for this purpose, because it is essentially carbonate of lime and, being white, is readily discernible. To comply with the Federal Coal-Mine Safety Act amendment of 1952, rock dusts must contain not more than 5 percent of free and combined silica and must be ground so that 100 percent will pass through a 20-mesh screen and 70 percent or more will pass through a 200-mesh screen.

Sewage Filter Beds

Crushed limestone is satisfactory for sewage filter beds. Either high-calcium or dolomitic limestone may be so used, and siliceous impurities are not objectionable if they are fine grained and evenly distributed. Certain other impurities, notably pyrite, marcasite, and clay, are to be avoided. The stone should be strong and compact, with pore space evenly distributed, and the fragments should be rough to provide anchorage for bacteria. Fines and dirt should be screened out.

Stucco and Terrazzo

Dense, compact limestones of attractive colors may be crushed into small fragments for terrazzo floors, but marble chips that will take a polish are generally preferred. Limestone reasonably impervious to moisture finds some use in stucco and pebbledash work.

Poultry Grit

Limestone crushed to granules and screened to uniform sizes is sold for poultry grit. Almost any type of limestone may be so used. The products may be graded by sizes into turkey grit, chicken grit, pigeon grit, and bird grit.

Sand

Limestone crushed to the size of sand grains, when carefully washed and graded, may be substituted for silica sand in mortar, wall plaster, and concrete. Large tonnages of limestone sands have been used in concrete highway construction in the Middle West.

Roofing Gravel

Screened limestone chips are sold as gravel to be used with tar for coating flat roofs.

Yard and Playground Surfacing

Limestone screenings without a binder afford good surfaces for school yards, playgrounds, walkways, station platforms, and tennis courts.

Concrete-Block Manufacture

Limestone screenings are used as aggregate in manufacture of concrete blocks, and limestone chips may be embedded in the surface to make the blocks resemble cut stone.

Chalk, Whiting, and Whiting Substitutes

Chalk is a soft, friable, fine-grained, light-colored type of limestone. The distinguishing physical characteristics of true chalk have never been fully defined; probably its noncrystalline and colloidal properties are most important. Whiting is a pulverized, purified, and carefully sized chalk. Whiting substitutes consist of finely ground limestone or dolomite, ground marble, white marl, and also chemically precipitated calcium carbonate. Very little true chalk has been produced in the United States.

True whiting is preferred for calcimine and cold-water paints and in the manufacture of putty. Both true whiting and substitute materials are used as ceramic raw materials and as fillers in numerous products, such as rubber, paint, paper, oilcloth, window shades, and linoleum.

Uses for Which Chemical Properties Are Most Important

Cement Manufacture

Limestone is the chief raw material used in making portland cement. Although pure limestone is not required, constancy in chemical composition is desirable. The general requirements are: (1) The stone should be free of concretions rich in iron minerals; (2) the silica and alumina contents should be sufficiently low and in such proportions that they will not interfere with the desired silica-alumina ratio in the finished product; (3) the magnesium content should be low enough that the finished product will not contain more than 5 percent magnesia (MgO); (4) the content of iron should be low enough that the ferric oxide content of the cement does not exceed 4 percent: (5) the sulfur content should be low.

Cement rock is an argillaceous limestone that contains enough clay as it occurs in nature to adapt it for the manufacture of cement. Sometimes it may be necessary to adjust its composition by adding small quantities of either high-calcium limestone or clay.

Lime Manufacture

For lime manufacture limestone must conform with rather rigid physical and chemical requirements. Exceptionally pure stone, total carbonates ranging from 97 to more than 99 percent, is generally used because virtually all impurities remain in the lime that results from calcination. The most common impurities are silica, alumina, iron, and sulfur. For shaft-kiln operation the stone should be sound and compact because porous and friable types break down during calcination and the fines retard the draft. For the same reason fines are screened from the kiln feed. For rotary-kiln operation finer materials may be used. Both high-calcium and high-magnesium stones are used. More detail on lime manufacture appears in another Bureau report (3).

Agricultural Uses

The most important uses for limestone in agriculture are as fertilizer, soil conditioner, and corrective for soil acidity. Pure limestone is desirable but not essential, because, although ordinary impurities lessen the percentage of calcium or magnesium available for improving the soil, they are not injurious to plant growth. Therefore, it may be more economical to use a local impure limestone than to purchase high-grade material that must bear a relatively heavy transportation charge. There is some difference of opinion regarding the suitability of dolomitic limestone, but most authorities agree that magnesium is of equal value with calcium and that the value of stone for agricultural purposes may be measured by the percentage of total carbonates present. Dolomitic limestone is preferred for magnesium-starved soils.

Small quantities of limestone are used in commercial fertilizers as diluting material or filler. Pulverized limestone is also added to stock food as a bone builder.

Mineral Wool

The name mineral wool or rock wool is applied to interlaced threads or filaments of mineral silicates used chiefly in heat insulation. It is usually made by melting argillaceous limestone, slag, or other calcareous and siliceous compounds in a cupola furnace and blowing the molten material into fine threads with a steam jet. The combination of raw materials most desired is one that will melt into a liquid slag at a relatively low temperature. Substantial quantities of siliceous and argillaceous limestones are used.

Chemical and Industrial Uses

Limestone is an important raw material used in metallurgy and in many chemical industries, such as alkali, calcium carbide, sugar, paper, and glass manufacture. Information on such uses is given in some detail in another publication of the Bureau of Mines and will not be repeated herein (7).

Uses of Dolomite and High-Magnesian Limestone

Some uses for which a magnesium content is essential or preferred are covered in preceding sections of this report. There are, in addition, several special uses.

Dolomite is employed extensively as a refractory lining in metallurgical furnaces. It is generally dead burned, but, particularly for patching, it may be used raw. A dead-burned product is made by calcining the dolomite at about 1,500° C., usually with addition of roll scale or iron oxide.

Dolomite is used to manufacture basic magnesium carbonate (technical carbonate), which is employed with addition of asbestos for making "85-percent magnesia" pipe and boiler covering.

During recent years dolomite has been employed as a source of magnesium metal.

Dolomite is widely used for calcining into lime. As indicated in the discussion of chemical and industrial uses in Information Circular 7402 mentioned previously (7), dolomitic limes have certain special uses, but they are also used extensively in the building trades, particularly in finishing-coat plasters.

Further details on the uses of dolomite are given in a Bureau report (8).

Distribution of Deposits

Deposits of limestone occur in all States, and in 1952 were utilized commercially in every State except Delaware, New Hampshire, and North Dakota. In some States deposits are very extensive and are quarried in many places. The general distribution of limestones and dolomites is indicated in the following sections. More detailed information on the locations of dolomite deposits is available in another Bureau of Mines report (18).

New England States

Many of the limestones of New England are so highly crystallized that they are classed as marbles. In Maine steeply dipping beds of crystalline limestone occur near Rockland and are utilized for lime and cement manufacture. A massive type occurs in Aroostook County.

In Vermont massive limestones are found principally in the northwestern counties. Waste marble in the Rutland County area is used at times as limestone. Low-magnesian limestone appears in northern Rhode Island. Large deposits of limestone and dolomite occur in western Connecticut and Massachusetts. Small occurrences in New Hampshire are of no commercial importance.

New York, New Jersey, and Pennsylvania

In New York limestones occur extensively in the counties between the Adirondacks and Lake Ontario, and crystalline dolomite occurs in St. Lawrence County. Limestones also crop out to the south in Herkimer, Saratoga, Washington, and Warren Counties and in a small area in the Champlain Valley. Another formation containing stone of 95 percent or more calcium carbonate crops out at various points in the eastern Adirondacks from Saratoga County north to the Canadian boundary. Deposits are quarried along the lower Hudson River near Poughkeepsie. Important belts extend east from Buffalo and the Niagara district to Lake Oneida and southeast to the Delaware River. The principal centers of production are in the Hudson River Valley for the New York market; in Oneida, Madison, and Onondaga Counties in central New York; and in Monroe, Genesee, and Erie Counties for Buffalo and other western markets.

The coarsely granular, crystalline Franklin limestone, which ranges in composition from a nearly pure calcium carbonate to a dolomite, is the calcareous rock of greatest commercial importance in New Jersey. It is available in Sussex and Warren Counties. The Kittatinny magnesian limestone occurs in thick, highly folded beds that are most readily available in Sussex, Warren, Somerset, and Hunterdon Counties.

The limestone industries of Pennsylvania are in the lead of those in all other States. Their preeminence is due to the availability of an abundance of high-grade stone and to extensive markets, particularly for fluxing stone in the iron and steel industries, for aggregate in highway and building programs, and for raw materials for large cement- and lime-manufacturing industries. Those of greatest commercial importance are found in the central and southeastern counties and in an area north of Pittsburgh. Pre-Cambrian limestones occur in Chester, Bucks, Berks, and Northampton Counties. Cambro-Ordovician limestones appear in a valley that crosses the State through Easton, Allentown, Lebanon, and Chambersburg and in Lancaster and York Valleys. An argillaceous phase constitutes the well-known cement rock in the Lehigh Valley district. The Helderberg and other limestones occur in narrow, curving bands in south-central Pennsylvania. Carboniferous limestones are widespread throughout the north-central and western half of the State. Pennsylvania limestones have been described in detail (13).

Maryland, Delaware, Virginia, West Virginia, North Carolina, and South Carolina

Limestones appear prominently in Carroll, Baltimore, and Harford Counties, Md. Washington, Frederick, Allegany and Garrett Counties in western Maryland also have numerous deposits that are utilized for making aggregates and also for lime and cement manufacture.

High-grade limestones of the Shenandoah Valley of Virginia and West Virginia have great commercial value. They occupy much of the two western tiers of counties throughout the entire length of Virginia. Lime manufacture is an important industry in this area. Limestones occur in the western counties of North and South Carolina but are not utilized extensively. Marls are abundant on the coastal plain of Virginia, North Carolina, and South Carolina.

Tennessee, Mississippi, Alabama, Georgia, and Florida

Limestone deposits are extensive in Tennessee, particularly in the central and eastern parts. The Holston formation includes the well-known marble belt of the Knoxville area. Limestones are utilized widely in middle and eastern Tennessee, particularly in Knox, Rutherford, Coffee, White,Cumberland, and some other counties. Cement, lime, and aggregates are the more important limestone products.

Limestone beds are utilized to some extent in the vicinity of Vicksburg and Jackson, Miss. The Selma chalk crops out in a zone about 30 miles wide in the northeastern counties.

High-quality limestones are abundant in Alabama. They are quarried extensively in the Birmingham area, particularly to supply furnace flux and lime. Important centers of production are in Blount, Etowah, Shelby, and Jefferson Counties. Dolomite is quarried in Jefferson County.

The commercial limestones of Georgia are confined chiefly to the northwestern counties - Polk, Dade, Bartow, Fannin, Gilmer, Cherokee, and Pickens. They are used chiefly for lime and cement manufacture and as aggregates.

Limestones are plentiful in Florida, but many of them are the soft, friable shell types. The Tampa limestone of the west-central counties is fairly hard and compact. Coral and oölitic limestones form the foundation of the Keys and border the east side of the Everglades.

Wisconsin and Michigan

Limestones are extensive in the north-central and northern sections of Wisconsin, appear in a broad belt along the eastern border of the State, extend across the southern counties, and are available in some areas along the western side. Nearly all of them are dolomites or high-magnesian limestones. Quarries are numerous, and their chief products are lime and aggregates.

Important limestone deposits border the northern part of the Southern Peninsula of Michigan. What is probably the largest limestone quarry in the world is at Rogers City, Presque Isle County. Other important deposits are in the Northern Peninsula. Deposits of commercial value appear also in a belt through Lenawee, Monroe, and Wayne Counties in southeastern Michigan, in several southern counties, and in an area near Saginaw Bay. The entire range of limestone products is made of Michigan limestone. Large quantities are shipped by water to other States.

Illinois, Indiana, Ohio, and Kentucky

Commercial limestones of both the high-calcium and dolomitic varieties occur in about one-third of the area of Illinois, including the northern end and belts along the western and southern borders. Scattered deposits of less economic importance are found in the remaining two-thirds of the State. The aggregate industries of the Chicago area are extensive.

Limestones occur widely in Indiana, the most important beds forming a belt about 20 miles wide extending northwestward through the central part of the State and including the famous oölitic building limestones quarried in Lawrence and Monroe Counties. Owen, Crawford, Harrison, and Washington Counties have high-calcium deposits. Farther north magnesian limestone occurs in several counties. Aggregates and cement are the leading products.

Limestones underlie a large part of Ohio. Dolomite of high purity in Wood, Sandusky, Ottawa, and several other counties is used extensively for magnesian lime manufacture. A second area farther south extending as far as Columbus has deposits of high-calcium and low-magnesium limestones. High-calcium stone occurs also in eastern Ohio and dolomite in Adams County in the south. Ohio leads all the States as a producer of lime, has a large cement industry, and ranks high as a producer of fluxing stone, aggregates, and many other products.

Kentucky is underlain with the same limestone formations that occur in Illinois, Indiana, and Ohio, and they appear in many eastern, southeastern, central, north-central, and western counties. Quarries producing crushed stone are operated in 30 or more counties distributed in various parts of the State.

States Between Mississippi River and Rocky Mountain Area

In Minnesota commercial limestones occur only in the southeast. Nearly all of them are high in magnesium, and many are nearly pure dolomites. Minnesota is well supplied with sand and gravel, and both traprock and granite are available in places, hence limestone is not used extensively as aggregate. The largest quarries are in the vicinity of Minneapolis and St. Paul. No lime or cement is made from Minnesota limestones.

The only limestone formations of North Dakota are argillaceous, chalklike beds in the far north and thin, more or less cherty beds, occurring as the upper strata on buttes in the western area. They are not utilized commercially.

Hard limestones occur in the Black Hills district of South Dakota. They are utilized for aggregate and sugar manufacture and for making cement and lime in Pennington County. They are quarried also at times in Custer, Lawrence, Fall River, and Meade Counties.

Limestones are abundant in Iowa. The dolomitic limestones of the eastern and northeastern counties are those most widely used for aggregate, ballast, flux, and agricultural and various other uses. Stone for similar applications is quarried in the central counties and in the extreme southeast. Limestones are quarried extensively in central and northern Iowa and in Scott County on the eastern border for cement manufacture.

The more important limestones of Nebraska are those of Pennsylvanian age in the southeastern area. Cass and Serpy are the most productive counties. The Niobrara chalk formation is utilized for cement manufacture in Nuckolls County.

Limestones are abundant and widely distributed in Missouri. Dolomites abound in southeastern counties, and low-magnesian limestones, mostly of high purity, crop out along the Mississippi River at various points from Cape Girardeau north to Marion County. High-calcium limestones occur along the Missouri River and in southwestern counties. The most important aggregate-producing areas are in the vicinity of St. Louis and Kansas City. Important cement and lime industries are centered chiefly in the eastern counties.

Commercial limestones are confined chiefly to the eastern third of Kansas. They are used extensively for cement manufacture in the southeastern corner of the State. Limestones in the southeast, in the Kansas City area, and at various other points are quarried for aggregate and other crushed-stone uses. Cretaceous chalk abounds in western Kansas but has little commercial importance at this time.

The principal limestone area of Arkansas lies in the northern part of the State in the Ozark Plateau. The most important is the Boone formation, with a maximum thickness of 425 feet, extending from White County to the Oklahoma line. The limestone of Marion County was used as aggregate for constructing Bull Shoals Dam on the White River. The chalk formations of the southwest have been utilized to some extent.

The commercial limestones of Louisiana are confined to 2 occurrences - 1 in Winn and the other in Evangeline Parish. Oystershells are utilized on the Gulf coast.

The largest limestone area in Oklahoma is in the east-central Arbuckle Mountain district. Quarries producing crushed stone are operated in Murray, Coal, Atoka, Pittsburg, and several other counties.

Limestones are distributed widely in Texas, particularly in the eastern half of the State. The Austin chalk occurs in a well-defined belt running from the Red River in the northeast west through central Texas and then south and southwest, terminating near San Antonio. It is important as a raw material for cement manufacture. Other limestone beds parallel to this formation lie to the west, and still larger areas are exposed in the Edwards Plateau west of San Antonio. Except for those near

El Paso the crushed-stone plants are chiefly in the east-central area. Asphalt-bearing limestones occur in Uvalde and Kinney Counties.

In Montana limestone occurs chiefly in massive beds along the flanks of mountain ranges in the western part of the State. Rock of exceptional purity occurring in Jefferson County is used for furnace-flux and sugar manufacture. Other important quarry centers are in Deer Lodge, Gallatin, Powell, Granite, and Cascade Counties.

Limestones occur in many parts of Wyoming but have not been utilized extensively. The best-known deposits are in Albany, Laramie, and Platte Counties in the southeast and in Weston County in the northeast. High-calcium limestones suitable for sugar manufacture are available.

Colorado limestone deposits are in two groups - an eastern division forming a belt immediately east of the Front Range and a second division lying west of the range. Limestone of the eastern division extends from north of Fort Collins to the middle of Douglas County, passing a little west of Denver. It continues with interruptions through several south and southeastern counties. The best rock contains over 90 percent total carbonates. Some of the limestones west of the range are high quality, but their location has discouraged development. The largest operations are in Pueblo, Fremont, and Chaffee Counties. The stone is used for cement manufacture, furnace flux, furnace refractory, and sugar mills.

The limestones of New Mexico have been utilized to some extent in San Juan and San Miguel Counties.

Western and Pacific Coast States

The limestone deposits of Idaho occur chiefly in the southeastern and northern counties. Bannock and Cassia Counties near the southeast corner of the State supply stone for making cement and for aggregate, flux, and sugar manufacture. Stone for sugar manufacture is produced in Butte and Teton Counties also. Limestone applied to many uses is quarried at times in Kootenai, Bonner, Nez Perce, and Clearwater Counties in the far north. Lewiston, Lewis County, also in the northern area, is an important center of production.

The most important limestones of Utah are those occurring in the Wasatch Mountains in the north and north-central region, chiefly in Cache, Weber, Tooele, and Utah Counties. They are used chiefly in cement and lime manufacture, as furnace flux, and as aggregate.

Arizone limestones are not used extensively. They supply the large smelter industries of the State with moderate quantities of lime and fluxing stone. Production is centered in Cochise, Yavapai, Gila, and Maricopa Counties.

The principal limestones of Washington occur in western counties from Seattle to the Canadian border. High-quality rock occurs on Orcos and San Juan Islands, San Juan County. Other deposits are in Stevens and Pend Oreille Counties near the northeast corner of the State. Washington limestones are used chiefly for cement and lime manufacture.

Oregon limestones occur in three widely separated localities - the southwestern, the northwestern, and the northeastern. Those in the southwestern area in Jackson and Josephine Counties are relatively pure and are suitable for lime burning and chemical uses. Most of those in Clackamas and other northwestern counties are

impure but are suitable for making cement. High-quality limestones are available in Baker County, northeastern Oregon. Deposits are found also in Grant, Union, and Wellowa Counties in the same section.

Limestones are available in various places in the eastern third of Nevada, but few quarries have been opened because of limited markets. Those in Clark and White Pine Counties are utilized for lime manufacture and metallurgical applications.

Few extensive limestone deposits comparable with those in many of the Eastern States occur in California. Most of the deposits in California are irregular bodies of variable magnesium content. Limestone deposits that are available are used extensively in the more populous areas. Cement manufacture is an important industry, particularly in the Los Angeles area where several large plants operate in San Bernardino, Riverside, Los Angeles, and Kern Counties. These counties are also important centers for lime manufacture and production of crushed-stone aggregate. Other limestone operations are in the following counties, beginning in the southern part of the State: Tulare, Inyo, Monterey, San Benito, Tuolumne, Santa Cruz, Eldorado, Centra Costa, Calaveras, Placer, and Shasta. Virtually the entire range of limestone products originate in the State.

Limestones occur in several places in Alaska. Beds of commercial quality occur in the Alaska Railway belt. They have been described in detail in a Bureau of Mines report (16).

A large deposit of relatively pure limestone containing about 97 percent $CaCO_3$ occurs near Edna Bay, Kosciusko Island, which lies northwest of Prince of Wales Island in southeastern Alaska. It has been explored and tested by a prospective user, but results of the exploration are not available. Limestones occur also on Dall Island near the south end of Prince of Wales Island. They have been quarried and shipped to the State of Washington for cement manufacture. A deposit of limestone is reported on Haceta Island.

Prospecting and Development

Determinations of the extent and quality of a limestone deposit should be made before development work is begun. If the rock crops out in such a way that both area and thickness of the beds are shown, a rough estimate of its quality and probable extent can usually be made. Limestones are as a rule fairly constant in composition throughout a single bed or unit of deposition; the greatest variations are found in passing from one bed to another. Therefore, all beds that may be included in a quarry are usually sampled. If a cross section is not available in nature, test holes are drilled at such intervals as will supply adequate data covering the whole area under consideration. Churn drills are usually employed, and cuttings for analysis are taken at regular intervals. No definite rules can be given either for position or arrangement of the holes. In flat-lying beds of uniform thickness and fairly constant composition they may be spaced at wide intervals - 100 or even 500 feet or more. Where beds are folded or tilted or where changes in composition or structure occur within short distances, they should be more closely spaced. Accurate, permanent records should be kept for all drill holes. When the dimensions of a deposit are known the approximate tonnage may easily be determined. Limestone weighs on an average about 160 pounds a cubic foot. To determine the approximate short tons available, the length, width, and depth in feet may be multiplied and the product multiplied by 160 and divided by 2,000.

For permanent installations a reserve of good rock sufficient for at least 20 years' operation is desirable.

Stripping

Stripping is the process of removing the overburden from the rock surface. The depth of overburden may vary from a few inches to 10, 20, 30, or even 40 feet. Likewise the nature of the material composing it is variable. It may be easily disintegrated loam, sticky, plastic clay, sand, gravel, boulders or a hardpan that may require blasting. The presence of erosion cavities in the limestone surface may make stripping difficult. Many different stripping methods are employed. The more important are the hydraulic method, dragline scraper, power shovel, and clamshell bucket worked from a derrick arm. Several types of efficient modern earthmoving machines are now available for heavy stripping, but the old-fashioned pick and shovel may be necessary to clean out mud seams.

Mining Methods

When beds are tilted at steep angles and are many feet thick an open quarry may be worked to considerable depth, but removal of waste to avoid dangerous overhang involves ever-increasing expense as the floor is deepened. When tilted beds are thin, any lateral extension must be in the direction of strike or outcrop. The narrowness of the working face on a thin bed cramps operations and makes it difficult to obtain large daily tonnages. Underground methods are commonly followed where the overburden is excessive or where comparatively narrow beds stand at steep angles. Underground methods have been described in detail in a Bureau report (17).

Drilling

The churn drill, commonly called the well drill, is widely used for primary drilling. Hand-manipulated, compressed-air hammer drills, using hollow drill steel, are so employed to some extent, but they are used chiefly in secondary drilling, that is, in block holing to break up the larger fragments. Detachable bits are now in common use.

Blasting

Heavy blasting to break rock from the parent ledge is known as primary blasting. A series of deep drill holes in 1, 2, or more rows may be fired at 1 time, throwing down a large mass of rock. Heavy blasts in churn-drill holes are usually considered the most effective. However, advocates of small-hole blasting claim that more general distribution of the explosive throughout the rock mass breaks it more completely and requires less secondary breaking than is usually needed for churn-drill blasting. Undoubtedly different results are obtained in different types of rock. Blasting in deep churn-drill holes is the method commonly employed. The charge in each hole should be regulated according to the estimated tonnage of rock to be moved. In average practice a pound of 40-percent dynamite shatters 3 to 6 tons of rock. The amount depends upon the toughness of the rock.

When electric detonators are used to fire the charges, the drill holes may be connected either in series or in parallel. Another method of firing is to use a detonating fuse such as primacord, the main line of which has a branch to each drill hole. A single detonator fires all the charges at virtually the same time. Such blasting is usually avoided in thickly populated areas.

It has been found that blasting costs can be reduced and rock fragmentation improved by using millisecond-delay blasting methods. The short time intervals between blasts in successive drill holes tend also to reduce earth vibrations that might, under ordinary conditions, damage nearby buildings.

To promote blasting efficiency many quarry superintendents keep accurate records that show for each shot the number and depth of holes, spacing, burden, kind and weight of explosive in each hole, tonnage of rock moved, and condition of fragmentation.

"Secondary" reduction is the process of breaking blocks of stone too large for loading. "Blockholing" is the method most commonly used. Holes several inches deep are sunk with a jackhammer drill, and a stick or part of a stick of dynamite with a fuse attached is placed in each hole. Rock dust or clay is used for stemming. Several shots may be fired in rapid succession.

At many quarries secondary blasting has been superseded by use of the ball breaker, sometimes called a "drop ball." A heavy mass of steel that may weight up to 7,000 pounds is hoisted by a crane and dropped on the block of stone. It is said to give more rapid results at lower cost than blasting.

Loading

Loading is a large item in quarry cost. Hand loading, which was formerly common practice, is still used in small quarries or where careful selection of stone is desired, but power shovels are virtually indispendable in the average quarry. Dipper sizes range from 3/4 yard to 1-1/4 yards for the smaller quarries and 1-1/2 to 4 cubic yards or greater capacity for the larger quarries. (See figs. 2 and 3.) The size should be proportional to crusher capacity. Electric shovels are now most common, although other types are also used. Steam shovels are now rarely used. Bulldozers are employed widely to repair roadbeds, collect scattered stone fragments, and perform other useful services.

Haulage

Haulage involves the motive power and equipment required to convey rock from the loading point to the crusher. Some years ago the equipment used most extensively consisted of standard-gage or narrow-gage railroad tracks, locomotives, and side-dump or end-dump cars. These have now been superseded in most quarries by truck haulage, either as single units or as tractor-trailers. Many modern trucks are diesel powered for greater fuel economy (see fig. 4). Practice varies according to quarry conditions. Where moderate grades can be maintained the truck may carry the stone to the quarry bank; for steeper grades cable haulage may be necessary. In some instances the stone is conveyed from pit to bank by belt conveyor, or the primary crusher may be placed on the quarry floor and the crushed stone removed from the pit by belt conveyor.

Primary Crushing

Jaw and gyratory crushers are the more common types of primary breakers, although roll crushers are used at times. Hammer mills may be employed for the softer rocks. Jaw crushers may have openings up to 66 by 86 inches and gyratory crushers up to 84 inches. The crusher should be oversize rather than undersize in order that large rock fragments may be accommodated without bridging the crusher opening and thus stopping the crushing process. A vibrating pan or other type of feeder ahead

Figure 2. - Limestone is scooped from the quarry floor into a 22-ton truck by power shovel at Jones and Laughlin Steel Co. quarry in West Virginia.

Figure 3. - Electric shovel with 1-½-yard bucket, loading limestone into a diesel-powered truck in Barberton, Ohio.

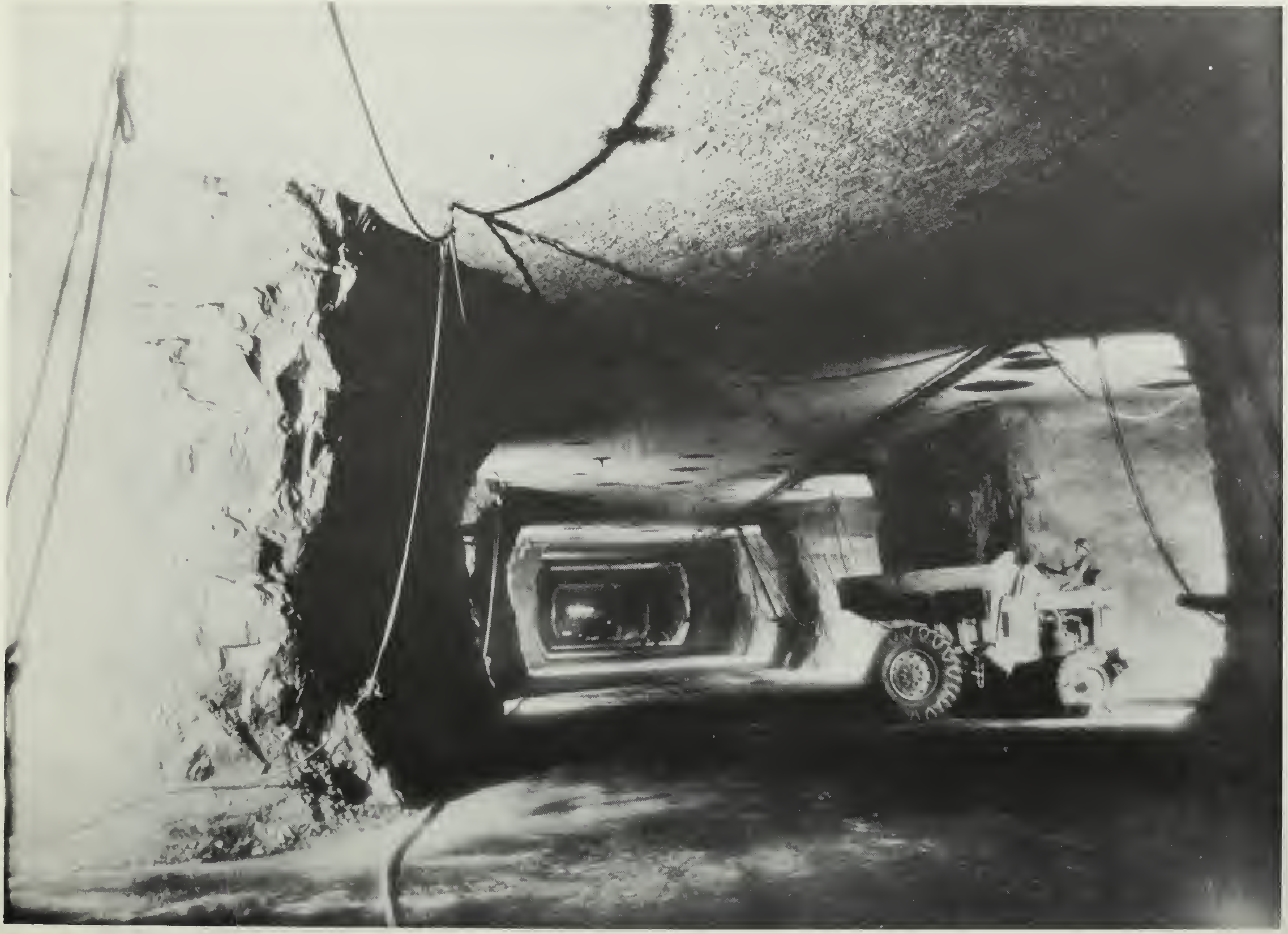

Figure 4. - One of the diesel-powered trucks used for hauling limestone from working faces to shaft in Barberton, Ohio.

of the primary crusher tends to minimize clogging and promotes a steady flow of stone to the crusher, enlarging the crusher capacity.

Secondary Crushing

Market demand may call for smaller-size stone than that produced by the primary crusher. Also there is at times a heavy demand for stone of the finer sizes for highway maintenance. Cone crushers, small-size gyratory crushers, or hammer mills may be used to reduce the primary-crusher product to 1 inch or smaller.

Fine Grinding

Finely divided limestone has many uses. Small, modified gyratory crushers, rolls, hammer mills, and rod mills are commonly used as reduction units. Even micronizers may be used to reduce the stone to extremely fine powders.

Screening

For the larger sizes a railroad-rail bar grizzly having 3- to 5-inch openings is sometimes used. The revolving trommel used extensively some years ago has been superseded by the vibrating screen, although trommels are still used as scalping screens for the larger sizes. The vibrating screen, which was used originally for fine sizes only, is now used for all sizes. Vibrating screens are made in single, double, triple, and even quadruple decks. Vibrating screens for fine sizes are sometimes heated to prevent clogging. Another type of screen is the live roll grizzly, sometimes called the cataract grizzly, or multiroll sizer. It consists of a series of rotating disks having spaces between them through which the finer stone drops.

Washing

During early years crushed stone was seldom washed, but modern specifications have placed such restrictions on fines and dust that washing is now common. A coating of dust can be easily removed by directing a fishtail water spray on the stone during its passage over the screen. Sticky clay or other impurities that adhere closely to the stone are more difficult to remove. Various types of scrubbers or log washers may be used. The log washer consists of a series of rotating paddles, which agitate the stone in water and carry it up an incline against a countercurrent of clean water.

Marketing

Crushed stone is low-priced and has a relatively limited market range, as the transportation charge is usually a large part of the delivered price. Profitable operation depends largely on the extent of local markets. Much of the crushed stone produced goes into highway construction, and more active markets in this field are to be expected if planned extensive highway programs materialize.

Market requirements for aggregates are becoming increasingly rigid. Quality and screen sizes are governed by specifications of the various State highway departments and by those of the American Society for Testing Materials, the Federal Specifications Board, and the Association of State Highway Officials and by the numerous specifications for building projects under the control of private and Governmental agencies.

Demands for aggregate are seasonal. Shipments reach a minimum in winter months except in Southern and Pacific Coast States. Stone for metallurgical and chemical uses moves more regularly.

Producers are most concerned about steady market requirements of nearby builders, contractors, State highway departments, and other users. The prudent operator gages his plant capacity by the normal demand but is prepared to profit by any extraordinary market opportunities.

Demand for aggregates is influenced by availability and cost of such substitute materials as sand and gravel or slag. In the building trades concrete products in which aggregates are used must compete with brick, stone, wood, and other materials.

Prices

Some years ago current prices of crushed stone were quoted in market reports. About 50 quotations represented the chief marketing centers. Prices were so variable from place to place that quotations were abandoned. The selling price is a problem for each producer. It depends upon volume, prices of competitive materials, and various other local factors. Average selling prices f.o.b. plant for the United States and for each producing State for any year may be determined by consulting the annual Stone chapters of the Minerals Yearbook, published by the Bureau of Mines.

Prices of crushed and broken limestone have not advanced during recent years as greatly as those of many other building materials. Average prices f.o.b. crushing plant, at 5-year intervals from 1932, were as follows: 1932 - $0.88; 1937 - $0.91; 1942 - $0.96; 1947 - $1.20; 1952 - $1.36. Constantly increasing efficiency of equipment and methods, together with near-capacity output, have permitted prices to be maintained at a comparatively low level, even in recent years when labor and machinery costs have increased greatly.

Royalties

Many crushed-limestone producers operate in deposits they do not own. It is customary in such instances to pay the owner of the property a royalty of so much per ton of crushed stone sold. Royalties vary greatly, depending upon local conditions. They may range from 2 to 10 cents or possibly more than 10 cents per ton. The lower figures usually prevail where production is large, but sales value per ton, production costs, or competition may influence the amount. A minimum average daily or monthly production is usually a condition of a royalty agreement.

BIBLIOGRAPHY

1. BOWLES, OLIVER. The Stone Industries. McGraw-Hill Book Co., New York, N. Y., 2d ed., pp. 33-66, 377-492.

2. _____. Dimension Stone; chap. in AIME Ind. Min. and Rocks. 2d ed., 1949, pp. 313-344.

3. _____. The Lime Industry. Bureau of Mines Inf. Circ. 7651, 1952, 43 pp.

4. _____. Rock Quarrying for Cement Manufacture. Bureau of Mines Bull. 160, 1918, 160 pp.

5. _____. The Economics of Crushed-Stone Production. Bureau of Mines Tech. Paper 12, 1931, 62 pp.

6. BOWLES, OLIVER, and MYERS, W. M. Quarry Problems in the Lime Industry. Bureau of Mines Bull. 269, 1927, 97 pp.

7. BOWLES, OLIVER, and JENSEN, NAN C. Industrial Uses of Limestone and Dolomite. Bureau of Mines Inf. Circ. 7402, 1947, 19 pp.

8. COLBY, SHIRLEY F. Occurrences and Uses of Dolomite in the United States. Bureau of Mines Inf. Circ. 7192, 1941, 21 pp.

9. DE VITRY, P., and MOULD, W. P. The Wire Saw in Quarrying Dimension Stone. Trans. AIME, vol. 173, 1947, pp. 245-251.

10. GOLDBECK, A. T. Crushed Stone; chap. in AIME Ind. Min. and Rocks. 2d ed., 1949, pp. 245-293.

11. KESSLER, D. W., and SLIGH, W. H. Physical Properties of the Principal Commercial Limestones Used for Building Construction in the United States. Nat. Bureau of Standards Tech. Paper 349, 1927, 94 pp.

12. LOUGHLIN, G. F. Indiana Oölitic Limestone, Relation of Its Natural Features to Its Commercial Grading. Geol. Survey Bull. 811, 1930, pp. 111-202.

13. MILLER, B. L. Limestone of Pennsylvania. Topog. and Geol. Survey Pennsylvania Bull. M7, 1925, 368 pp.

14. NEWSOM, J. B. Results of Wire-Saw Tests. Trans. AIME, vol. 102, 1932, pp. 117-121.

15. NEWSOM, J. B., and BOWLES, OLIVER. A New Adaptation of a Wire Saw. Eng. and Min. Jour., vol. 124, 1933, pp. 506-508.

16. RUTLEDGE, F. A., THORNE, R. L., KERNS, W. H., and MULLIGAN, J. J. Preliminary Report: Nonmetallic Deposits Accessible to the Alaska Railroad as Possible Sources of Raw Materials for the Construction Industry. Bureau of Mines Rept. of Investigations 4932, 1953, pp. 90-123.

17. THOENEN, J. R. Underground Limestone Mining. Bureau of Mines Bull. 262, 1926, 100 pp.

18. WEITZ, J. H. High-Grade Dolomite Deposits of the United States. Bureau of Mines Inf. Circ. 7226, 1942, 86 pp.

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INTERNATIONAL COOPERATION IN REDUCING MINE HAZARDS

By E. J. Gleim

United States Department of the Interior — February 1956

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UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
Thos. H. Miller, Acting Director

February 1956

INTERNATIONAL COOPERATION IN REDUCING MINE HAZARDS

BY E. J. GLEIM[1]

CONTENTS

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Information Circular 7739

SUMMARY

This report describes a trip to Europe in the interest of safety in coal mines. It reviews the Eighth International Conference of Directors of Safety in Mines Research, which met in Dortmund-Derne, Germany, July 5-10, 1954, to discuss results of studies made in different countries to improve health and safety conditions underground. It also summarizes information on subjects of special interest in the United States gained by the writer in visits to mining experiment stations in Belgium, France, and England.

The efforts being made to protect life and property underground were discussed, and ideas and experiences were interchanged freely, not only during the conference but also during visits to the several countries. Helpful information was obtained on many topics of interest, but time did not permit as thorough a discussion on some of them as might be desired.

INTRODUCTION

Engineers, research workers, and technicians looking for solutions to their problems often benefit greatly by participating in conferences with representatives of organizations working in similar fields. By formal and informal discussions about problems of mutual interest, they gain new ideas and a new outlook with which to attack their own. Thus, in the mine-safety field much good is derived from conferences where specialists in its various phases meet to review progress and to interchange ideas of common interest.

Preeminent among conferences dealing with the subject of safety is the biennial Conference of Directors of Safety in Mines Research. The eighth and latest was held July 5-10, 1954, at the Mining Research Station in Dortmund, Derne, Germany. Here, representatives of 14 nations met to present discussions of 46 papers prepared well in advance and to visit research and testing facilities. Those nations represented were: Austria, Belgium, Canada, England, France, Germany, Italy, Japan, Netherlands, New Zealand, Nigeria, Poland, Union of South Africa, and the United States. The subjects of the papers and the authors are listed at the end of this paper, and the list shows the wide range of topics included. There were too many papers to have them read during the formal sessions; consequently, the delegates were invited to prepare written discussions and questions in advance for presentation during these sessions.

The author, who attended the conference, found that Dr. H. Schultze-Rhonhof and members of his staff of the German research station had been most thorough and efficient in arranging a program for the comfort, convenience, and instruction of the delegates. Each day was divided into separate sessions or periods at which a different chairman presided, and a different topic was assigned for each session. In addition to the formal discussions, a "coffee break" each midmorning permitted the delegates to mingle freely and select those with whom they wished to continue discussions informally. Furthermore, evening banquets sponsored by German

organizations, such as the explosives industry, the electrical industry, the Coal-Mining Association, and the Westphalian Mining Union, also gave the delegates and representatives of the sponsoring hosts an opportunity to discuss mining problems. All this contributed greatly toward creating an atmosphere of international understanding and good will.

The official languages for the conference were English, French, and German. Each delegate wore a badge bearing his name, with the background colored to indicate the language spoken by the wearer. Thus, blue designated an English-speaking person; white, French-speaking; and red, German-speaking. During the conference sessions translators were stationed in seats in front of the speakers' table and made notes of the speakers' remarks and discussion. At the conclusion, the translators stepped into soundproof booths and repeated the remarks in the chosen languages. Then, by using earphones at each seat, each delegate could operate a selector switch and volume control on a ledge before him to hear the proceedings in the language of his choice. In addition, disk records were made of the discussions for future reference.

The program included visits to the various laboratories where testing methods were demonstrated and explained. Thus, delegates to the conference had an opportunity to obtain firsthand knowledge of equipment used and procedures followed in investigating mining equipment and materials, such as electrical units for machines, explosives, and lamps.

Moreover, as part of the program, special trips to points of interest had been arranged. For example, a limited number of delegates were taken to the Experimental mine near Dortmund where studies on the prevention of mine explosions, detonation products of explosives, rock-dust barriers, and other mine-safety subjects are conducted. Another trip was made to the mining museum in Bochum where there are exceptionally fine exhibits with small-scale models illustrating mining methods, tools, and equipment dating from ancient to modern times. Underneath the museum are areas that simulate underground conditions in a German coal mine, with actual machines and equipment in place.

A third trip was that made to the Mine Rescue Station at Essen. This station is 1 of 3 that are responsible for rescue operations in prescribed mining areas. A fourth station is now under construction. The Essen area is the largest of the three; it is about 30 by 70 miles in extent and includes 154 collieries, 57 coke plants, and 72 byproduct plants. The Essen Station specializes in training leaders in mine rescue operations and rescue work in industrial plants. During 1953, 350 men were trained in 19 courses, lasting 6 days each. The training course is rigorous. In addition to lifting weights and climbing ladders, the trainee (wearing breathing apparatus for mine work) must travel through a four-tier structure in which there are obstacles to get over, through, and around. Less elaborate equipment is available for training rescue workers in industrial plants. The station facilities also include arrangements whereby a number of sets of breathing apparatus may be washed, sterilized, and tested simultaneously. Other activities of the station include: Investigation of self-rescuers, test and certification of fire extinguishers, and analysis of gas and air samples. In 1953, 2,350 such samples were analyzed. The station is well stocked with supplies and equipment ready for use in mine rescue, fire-fighting, and mine-sealing operations.

ACKNOWLEDGMENTS

The writer is deeply grateful for the courtesies extended him by personnel of the mining experiment stations in Germany, Belgium, France, and England and for the valuable information gained from discussions with them and with officials connected with the coal-mining industry in those countries.

INFORMATION OBTAINED AT EUROPEAN MINING EXPERIMENT STATIONS

Since a number of the European mining experiment stations are within a relatively short distance of each other, the author visited several in Belgium, France, and England as well as Germany. In addition to a special assignment to obtain information on preventing conveyor-belt fires, it was desirable also to obtain information on other subjects related to safety in coal mines.

The Belgian station is in Paturages. The French station is at Verneuil, France. England has two stations at which experimental work is done; one of these is at Sheffield and the other at Buxton.

In the following pages the information obtained in the various countries has been classified according to subjects covered.

Prevention of Conveyor-Belt Fires

The discussion of Paper 24,[2] Measures for Preventing and Fighting Fires in Belt Conveyors, by Drs. W. DeBraaf and W. Maas of The Netherlands, showed that much experimental work has been done with flame-resistant belts in the different countries because of the severe losses suffered through fires with flammable belt-conveyor installations. The most disastrous of such fires was that at the Creswell colliery, Derbyshire, England, in 1950, which claimed 80 lives. In British mines there are 2,600 miles of belt installations. Because of the Creswell and other fires, the flammable belts are being replaced as rapidly as manufacturing capacity permits with flame-resistant types. These are manufactured with a polyvinyl chloride plastic (PVC) material. Experience with such belts in Germany was said to be much the same as in The Netherlands, in that they do not wear as well as rubber belts. A test belt made in The Netherlands with alternate sections, each 50 meters long, of PVC and rubber, showed that the PVC type had to be discarded long before the rubber. In England, where 29 types had been tried, it was found that more belts had to be removed because of edge wear than because of surface wear.

Statistics on belt fires have disclosed that most of them start at rollers that cannot revolve freely because of seized bearings or because of accumulations of coal and grease around them. The explanation given is that friction of the belt rubbing against retarded rollers causes the nearby material to glow; after the belt has been stopped (as at the end of the shift) the glowing material is fanned into flame, and the belt, being stationary, then easily catches fire. Another important origin of fires has been at the driving pulley owing to friction between the pulley and the belt when the latter has been stopped or appreciably slowed by roof falls or other causes. For this reason, it is important that belts be patrolled regularly to detect incipient fires, particularly after the belts have been shut down. In England it is considered dangerous to use rubber lagging on the drive pulley because slippage might cause overheating. Pulley temperatures must not exceed 180° C. In The Netherlands a 30-percent slip is not considered dangerous, as the belt will remain cool enough, even though the pulley heats.

[2] Papers prepared for the conference are listed by number in the Bibliography at the end of this report.

A number of temperature-sensitive devices have been developed to stop the driving motor when the pulley overheats. Some doubt exists in England concerning the merits of such devices. If there is too much lag in their response to rise in temperature, the danger point may have been passed before the motor is stopped.

In Germany one method of fire prevention employs two water-spray nozzles mounted above the driving pulley. The valves for them are electrically controlled by a small glass bulb filled with a liquid that expands and bursts the bulb when the surrounding temperature reaches 60° C. The glass bulb while intact keeps electric contacts separated in the valve-control circuit. It is understood that no special protective equipment is used in Belgium for belt installations.

In addition to protective devices at the drive end, a further precaution is to fireproof this area for 6 meters in each direction from the drive. Furthermore, a switch that can be operated from any point along the belt by a cord extending its full length is an important feature for stopping the drive motor in emergencies.

The importance of good housekeeping was stressed as a fire-prevention measure. It was considered essential not to allow coal to accumulate around rollers or along the belts. In Great Britain, belt roller supports are now required to be raised so that coal does not accumulate so readily around rollers.

Belts spliced with fasteners that leave a gap between the joined ends allow dust to fall through to the return side of the belts, contributing to spillage along the belts. It was found that this type of spillage could be reduced 95 percent by inserting neoprene strips in the gaps or by patching over the fasteners. In England a method of concentrating spillage at belt ends is under trial. This consists of reversing the belt at the drive end so that a clean belt travels back to the face. The disadvantage of this is that more space is required for the necessary equipment. Plastic belts have been found easier to keep clean than rubber belts.

Since authorities in Great Britain consider flame-resistant belts to be the best solution for the problem of fires, specifications and tests had to be drafted for determining flame-resistant properties and acceptability. To be approved for underground installation, belt samples must pass a friction as well as a flame test. In the friction test, a sample 5 feet long and 6 inches wide rests on a pulley or drum rotating at about 190 r.p.m., corresponding to an average belt speed of 330 f.p.m. One end of the sample is attached to a load-measuring device to check tension, and it is placed over the pulley so as to touch 180° of surface. The test is made both in still air and in an air current representing mine-ventilation current. The sample is regarded as having failed in either instance if flame or glow is detected or if the temperature of the drum exceeds 300° C.

For the flame test, 12 samples 12 inches long and 1 inch wide are used. These are held horizontally by 1 end, and a gas flame from a special burner is applied for 30 seconds at the other end; the top of the burner is 2 inches below the lower edge of the sample. Six samples are tested with outer covers intact; no flame or glow should be visible 3 seconds after the burner flame is withdrawn. The outer covers of the remaining 6 samples are stripped or buffed away, and the flame is applied as before for 30 seconds. Visible flame or glow must disappear in 5 seconds after withdrawal of the burner flame.

In constructing belts it was found essential to impregnate the individual cotton plies with PVC; otherwise, the belt would not pass the tests for flame resistance.

Each belt approved for underground use must be branded with the date of manufacture, and each manufacturer is assigned a certain color to facilitate identification of his product. The date and color thus become useful in comparing the performance of one belt installation against another.

It was brought out during the conference that authorities in England were concerned over the possibility that static electricity generated by plastic belts in motion could ignite methane. Sparks 3 to 5 mm. long and quite bright had been observed underground at old belts along dry roads. To trained observers these sparks appeared to be capable of igniting methane, but tests were to be made to verify this opinion. It was learned later that laboratory tests had shown that as much as 40,000 volts of static electricity developed on dry days with plastic belts, as against only 1,000 volts with rubber belts. Sparks were noted where metal belt fasteners passed over rollers.

Apparently, the same concern over possible gas ignitions underground with belt installations in The Netherlands was not shared by a delegate from that country. He stated that laboratory experiments had shown it possible to ignite gas and that some static had been noted with new belts along dry roadways when the humidity was less than 60 percent but that with normal humid conditions underground there appeared to be little danger of gas ignitions by static sparks.

Several ways of reducing the development of static electricity were proposed in England. So-called static-free plastic belts already are being manufactured. One opinion is that metal clips at relatively close intervals along the belt edges would help to prevent building up of static charges by contact of the clips with the rollers. Another suggestion was that water sprayed on belts should help reduce static charges, although an excess would cause the coal dust to cake and adhere to the belts. In France it is thought advisable to mount belt rollers on insulators and to vulcanize over the metal fasteners.

Flame Safety Lamps and Gas Detection

In spite of certain shortcomings, the flame safety lamp is still to be regarded as an important adjunct in insuring safety to underground workers at coal mines. This point was developed in Paper 23, Memorandum on the Detection of Fire-damp in Mines prepared by Dr. W. Maas of The Netherlands, and was also confirmed during the discussion. Although a considerable number of methane-detecting appliances have been devised, they do not indicate oxygen deficiency or concentrations of carbon dioxide. Accordingly, several countries are making efforts to improve safety lamps as to safety and reliability in gas detection.

The cerium-iron alloy pins used in relighting many safety lamps are regarded as dangerous. Dr. Maas' paper stated that abraded particles of the flint stone lodging in the heated gauze when the lamp was inverted caused ignition of gas surrounding the lamp. "Flint stone" is a term given to an alloy containing cerium, iron, and other ingredients. In discussing this problem with research specialists in England, it was learned that eight men in a mine-surveying group were burned in a gas ignition attributed to igniter particles in the gauze of a small lamp. The abraded particles when heated to 180° C., were found capable of igniting gas. In Paper 33, Dr. Karl Winter of Germany stated that, since a practical electrical igniter had been found, permits for use of lamps with cerium-iron igniters would be withdrawn after January 1, 1955, according to an order issued in December 1952 by the Mining Commission at Dortmund. Moreover, no new permits were to be issued after January 1, 1955, allowing the use of lamps with cerium-iron igniters.

Among the lamps exhibited at the conference were some fitted with an electrical igniter. This igniter was operated by a rod through the bottom of the fuel vessel. When this rod is pulled down, 2 arms with a fine platinum wire or filament about 1/4 inch long between their ends are moved to bring the wire over the wick tube. The motion of the rod also closes a circuit from a dry cell through the filament, which causes it to glow and ignite the fuel vapor at the wick. Retracting the rod raises the filament to its original upright position and also disconnects it from the dry-cell circuit.

In a visit to the mining experiment station in Belgium, it was learned that lamps with cerium-iron igniters were not permitted in Belgian coal mines.

The most severe test for lamps suspected of being defective is to attempt to relight the lamp in motionless explosive atmospheres. Such a test is most likely to reveal defects of a nature that would produce external ignitions. This viewpoint was confirmed in a discussion with personnel at the Sheffield, England, experiment station. It agrees with the position of the Bureau of Mines, United States Department of the Interior.

The equipment for testing flame safety lamps in moving explosive methane-air mixtures at the Belgian experiment station is much the same as that used by the Bureau of Mines, United States Department of the Interior. Operation of the equipment was demonstrated by testing a lighted Davy safety lamp. This ignited the mixture passing the lamp, proving that it is unsafe in atmospheres moving at velocities of over 500 f.p.m. It was learned here, too, that in constructing double-gauze lamps, the space between the tops of the gauzes must be less than 15 mm.; otherwise the lamp may be unsafe.

Improvement in the reliability and accuracy of flame safety lamps in detecting methane is being carefully studied in England at the Isleworth Laboratory, Central Research Establishment II, National Coal Board. Efforts are being directed toward developing a detector in which the flame of burning butane offers better characteristics than the ordinary flame in safety lamps.

Methane-Detecting Appliances

An entire conference period was devoted to discussing methane-detecting appliances. Two papers (10 and 33) had been prepared for the purpose. From the questions asked during the period it was apparent that the various countries are looking for portable methane-detecting instruments that are more suitable and accurate than flame safety lamps. Considerable interest was shown in the characteristics of American- and Japanese-made detectors, and it was learned that several types are being studied in several laboratories. In addition to the Riken interferometer type recently introduced into the United States, two others based on the same principle were found to be under study in Europe. One of these was made by the Seisakusho Co., Ltd., of Japan and the other by Carl Zeiss, Inc., in Germany. A "Mono" continuous methane recorder manufactured by H. Maihak A. G., Hamburg, Germany, was seen at the testing station in Belgium. This recorder employs an air turbine to drive a generator that supplies electric current for the combustion chamber. A clock movement drives the chart on which the record is made. The instrument can be set to give an alarm when the methan exceeds a predetermined value. A 0.25-percent error of indication is understood to be allowed in methane detectors in Belgium.

Methane Drainage

The large quantities of methane liberated in some Belgian mines have commercial value. Evidence of this fact was obtained in a visit to the office of the John Cockerill mine at Frameries, Belgium. Pipes cemented into holes drilled 60 to 100 meters deep into the coal seam and 25 meters apart are connected to a common main which hourly delivers on the average of 600 cubic meters of gas containing 75 percent of methane to a gas holder fed from several mines. From this point it is distributed to nearby factories. When the heating value of the gas from the mine drops below a prescribed value, an automatic device operates to stop flow of gas to the holder.

Explosion-Proof Mine Equipment

One of the demonstrations witnessed by delegates at the Dortmund-Derne experiment station was that showing the conditions under which ignition of explosive atmospheres surrounding an electric enclosure would occur in one instance but not in another. A cast-aluminum-alloy enclosure or box was used for this demonstration. Instead of being bolted, the cover was of sliding type, designed so that one side of it engaged with a tight-fitting groove machined in the box and a similar groove at the opposite side engaged with a lip of the box when the cover was in place. This design left 2 matching plane surfaces at the 2 ends of the box serving as flame paths with no means of keeping the plane surfaces together except the overlap of the grooves in the cover and box at the sides. The gap between these surfaces was said to be 0.3 mm.

The box was mounted in an upright, cylindrical testing chamber or gallery so that it could be filled and surrounded with an explosive mixture of "coal gas" and air. The gallery was approximately 4 feet in diameter by 4 feet in height and was closed at the top with a waterproof paper diaphragm resting on a rubber ring gasket. The diaphragm was held in place merely by resting an angle iron ring on it without fastenings of any kind.

For the first test, the mixture within the box was ignited by a high-tension electric spark. No external ignition occurred under this condition. For the next test, the mixture within the box was ignited by vaporizing a copper wire with short-circuit current. The copper wire was 1.5 sq. mm. in sectional area (between No. 15 and 16 A.W.G.) and 100 mm. (4 inches) long. In this instance the mixture surrounding the box exploded. The ignition was explained as being caused by incendive particles of the aluminum alloy box projected through the 0.3-mm. (0.012-inch) cap in the joint at the end of the box. Because this condition produced external ignitions, certification of this type of construction was no longer permitted after January 1, 1954. Accordingly, in subsequent boxes, a tongue-and-groove design was used for the joints at the two ends instead of plane surfaces.

In Europe the criterion for failure of an enclosure to meet explosion-test requirements is commonly the fact that the surrounding atmosphere ignited. In conducting the tests, observations for discharge of flame, sparks, and smoke from joints or clearance openings in the enclosure are not always made. This practice differs from that followed in the United States by the Bureau of Mines, United States Department of the Interior, in that observations are always made to determine where flame, sparks, and smoke are discharged. Moreover, if flames are noted, the enclosure is recorded as having failed to meet test requirements, even though no external ignition occurred.

The testing station at Dortmund-Derne is well equipped for explosion testing. The electrical testing laboratory was built within the last 2 years. Generating equipment capable of delivering high current at high voltage is available for making short-circuit and other electrical tests that may be desirable. This equipment includes a rotary converter with a maximum output of 400 kv.-a., which is designed for use within voltage limits of 0 to 800 volts, direct current, and 0 to 1,200 volts, alternating current. Also available is a turbogenerator capable of producing surge currents up to 20,000 a., effective. A transformer in the high-voltage test apparatus allows energy outputs up to 600 kw. in the range of 1.2 to 11 kv. In addition to the gallery previously mentioned, other cylindrical galleries are used in making explosion tests of electrical equipment. The vertical galleries are for testing smaller pieces of apparatus, while a horizontal gallery in sections is for testing the larger pieces. A 5-ton, hand-operated gantry crane is available for handling pieces for testing and for manipulating parts of the galleries. The testing facilities are described in Paper 42.

Four papers (11, 22, 42, and 45) bearing on the subject of explosion-proof enclosures had been prepared for discussion at the conference. Judging by the number of questions asked, there was considerable interest in the method followed in determining explosion-proof qualities of equipment in the United States, as described by Paper 11. Also, there was much interest in the type of construction followed in this country. The experience in the United States with distortion of enclosures under test was verified by that in The Netherlands, as expressed in Paper 22. This paper described an electrical method devised for measuring the amount of permanent, as well as temporary, distortion produced at the joint between an enclosure and its cover by an internal explosion.

The Belgian gallery for explosion testing of equipment is a horizontal structure; one end is closed with a door to permit entrance of equipment to be tested and personnel. A track is laid into the gallery so that a truck bearing the equipment for test may be taken in and out easily. Since ignition of the external mixture is the determining factor in recording failure under test, observers are not always stationed at the gallery windows. The source of ignition is usually at the center of the enclosure under test. This same gallery is used to test diesel locomotives.

Among the Belgian requirements for constructing explosion-proof electrical equipment is the limit of 0.1 mm. maximum separation of surfaces comprising flange joints 25 mm. wide and a 0.5 mm. maximum for joints 50 mm. wide. A minimum of 10 mm. is prescribed as the distance from the inside of an explosion-proof enclosure to the edge of a bolt hole through the flange joint. Flame arresters used for either electric or diesel equipment are required to have a path 50 mm. long between nonrusting plates. The plates must be 2 mm. thick, and the space between them must not exceed 0.5 mm.

In explosion-testing electrical equipment at the French experiment station, five tests usually are considered sufficient, and these are not always observed. Ignition of explosive mixtures surrounding an enclosure is the criterion for failure under test. The tests are made in cylindrical galleries having a vertical axis. Flame arresters used with explosion-proof electrical equipment must have plates giving a flame path at least 25 mm. long between them. The plate separation must not exceed 0.5 mm.

Various laboratories in England have studied problems associated with the design and construction of explosion-proof enclosures for electrically operated mining

machinery. At Buxton, in the laboratory of the Safety in Mines Research Establishment, for example, much experimental work has been done toward establishing "safe-gap" values. A safe gap may be defined briefly as the maximum separation between surfaces comprising joints that will not permit propagation of explosions within an enclosure to the surrounding explosive atmosphere. In testing enclosures for explosion-proof qualities at Buxton, it is seldom considered necessary to observe the enclosure directly. Failure under test is recorded only when the explosive atmosphere surrounding the enclosure is ignited by flames issuing from it.

Considerable interest was manifested in Europe toward a proposed international standard for constructing explosion-proof (flameproof) equipment. This was particularly evident in England through discussions with individuals and groups. For example, in a meeting in London with the British delegation preparing to visit the United States to attend sessions of the International Electrotechnical Commission at Philadelphia, opportunity was afforded to explain the Bureau of Mines requirements and methods of testing equipment for official approval.

Gas Ignitions by Frictional Sparks

Paper 5, Ignition of Explosive Gas Mixtures by Friction, brought out a very interesting discussion in one of the sessions of the Dortmund-Derne conference. It was learned that tools, such as hand-held drills, made of aluminum and magnesium alloys and props made of these metals were to be prohibited in safety-lamp mines of England after the close of 1954. One reason for this ruling was to prevent gas ignitions by sparks produced when such metals strike rusty steel.

In Germany, it was thought that ignitions from this source need not give grave concern as the magnesium content of light alloys usually was less than 1 percent. Opposed to this viewpoint however, was the opinion that until 2 years ago, ignitions attributed to unknown causes might actually have been caused when a light alloy struck an oxygen carrier (rust) and produced a thermit action.

It was stated that in Belgium sparks produced by light alloys have been suspected as a possible source of gas ignitions underground.

Gas ignition by sparks produced by cutting-machine bits has been the subject of special studies in England. This topic was discussed during the visit to the Buxton station. It was learned that some 10 ignitions a year occur when cutting machines are operated without water on the bits. On the other hand, there have been no reports of ignitions when cutting is done wet. When water was used on an experimental disk for producing sparks, it was found that the chance of ignition was reduced 50 percent. Air carried into the kerf by the water stream was said to help ventilate the undercut. But, if air is piped to the machine to ventilate the undercut, some arrangement such as an interlock between the air and electrical control would be necessary to insure that the air is turned on before the cutter bits are started. On the other hand, if methane is present in amounts above the upper explosive limit, air must be added with caution, as it might bring the mixture within the explosive range. Creating an inert atmosphere in the kerf with some gas such as nitrogen was thought to be a feasible way of reducing the ignition hazard. A search is being made for a special flowmeter type of valve to use on continuous mining machines so that the machines would be inoperative unless water is flowing to the cutting bits.

Multiple-Shot Blasting

Four papers (9, 21, 32, and 43) dealing with the subject of safety in blasting were discussed at the conference in Dortmund-Derne. Germany, it was stated, had no difficulties in multiple blasting when instantaneous electric detonators were mixed with short-delay detonators. One interesting comment was that adequate training of drillers and shot firers was important.

Small portable units are available in Germany for testing multiple-shot blasting machines. These are cylindrical, wax-filled boxes about 2 inches in diameter. The blasting machine to be tested is connected to two terminals in the top of the unit and when operated will light a small neon lamp under a glass-covered opening if the blasting machine is in satisfactory condition.

During the visit to the Belgian testing station it was learned that multiple blasting is permitted in mines of that country with up to 10 short-delay detonators in series. In discussing the advisability of mixing instantaneous with short-delay detonators in series for multiple shooting, the opinion was given that there should be no objection from the standpoint of possible misfires. However, in a demonstration arranged to substantiate this point, a zero-delay detonator was used as an instantaneous detonator in a series of 18 delay detonators having 25 to 30 milliseconds delay intervals. All 18 detonators fired when connected to the blasting unit. One type of blasting unit used in Belgium is spring operated. The key used to wind the spring also is used as the firing key, and the unit is designed so that the key cannot be removed for firing until the spring has been completely wound. Thus, variations in manual effort are eliminated as a factor in obtaining maximum output of blasting units. It is the opinion that blasting units (exploders) should be designed so that current will cease to flow in the blasting circuit at the end of 4 milliseconds.

A demonstration of the possibility of gas ignition by short-delay detonators was witnessed at the Belgian testing station. For this the detonator was suspended freely in a vessel containing an explosive gas-air mixture. Although the mixture was not ignited each time a detonator was fired, ignitions were frequent enough to prove that safeguards are necessary when these detonators are used in gassy mines. The opinion in Belgium is that there is a greater hazard of gas ignitions when multiple blasting is done in rock than in coal.

Tests to determine hazards associated with blasting in rock are made in a tunnel driven in hard rock. In a demonstration arranged for the benefit of the author, 2 holes were drilled about 2 feet apart in a hanging corner of rock at the right of the tunnel face. The upper hole was drilled to a depth of 1 meter 18 centimeters and the lower hole to a depth of 1 meter. Each hole was charged with 6 cartridges of explosives. In the upper hole the last cartridge inserted contained a zero delay detonator pointed away from the main body of the charge, and a No. 6 delay detonator was similarly placed in the last cartridge in the second hole. Stemming was tamped in each hole after the primer was in place. The selection of detonators provided for a delay of about 180 milliseconds between shots. A paper diaphragm was erected outby the face, and enough methane was admitted back of it to form an 8.75-percent mixture.

When the shots were fired the explosive mixture did not ignite. Examination later disclosed that 1 cartridge had not exploded in the upper hole and 2 or more had not exploded in the lower hole. It was explained that in this type of test, the gas has never ignited when the delay between shots was under 60 milliseconds but that ignitions were likely to occur when the delay was over 100 milliseconds between shots.

For studying the uniformity of detonator-timing characteristics, the equipment at the Belgian station includes a drum rotating at a constant speed of 200 r.p.m. covered with a photographic film which records the light flashes of the exploding detonators. The latter was inserted horizontally in holes possibly 3 inches apart in an upright piece of steel shafting, which is approximately 3 inches in diameter. The ends of the detonators are set to protrude about one-half inch beyond their holes in the shafting. The axis of the holes are at right angles to a vertical plane, which is determined by the axis of the shafting and the center of the lens in front of the photographic film. The sensitiveness of detonators is determined by apparatus that permits a predetermined value of current to flow for a chosen period of time. This period is adjustable through variable separation of two switches that are tripped in succession by the swing of a pendulum, the first one closing the circuit through the detonator and the second one opening the circuit. The duration of current flow is measured in milliseconds by a chronograph. A 20-volt battery supplies the firing current that is first adjusted through a circuit having a resistance equal to that of the detonator to be tested. Then, using switches, the battery is connected to the detonator circuit.

In France it was learned that no limit is placed upon the number of shots that can be fired simultaneously when multiple blasting is done in gassy mines. However, a 4-millisecond time limit is set as the maximum duration of current flow to the blasting circuit from multiple-shot blasting units.

Blasting units are tested in the laboratory at the Sheffield station in England. Six shots is the maximum number permitted during multiple blasting in British coal mines. A unit having a 67-volt dry battery and a 150-microfarad condenser was seen, including an instrument for determining the condition of the detonator circuit before firing. It had a scale divided into areas of different colors for indicating at a glance whether the circuit was normal, short circuited, or open circuited. The design was such that the switch for closing the firing circuit had to pass through the circuit-testing position before it could be moved to the firing position.

Diesel Mine Locomotives

One of the factories in Germany supplying diesel-driven mine locomotives is that of the Swarz & Dyckerhoff Co. at Mulheim. In a visit to this plant it was learned that among the types built is a diesel locomotive for operation in gassy coal mines. This type is fitted with flame arresters made of plates spaced 0.8 mm. apart. Formerly, a spacing of only 0.5 mm. was permitted. Locomotives are equipped with "inertia" starters. For fire fighting, nozzles connected by piping to a cylinder of carbon dioxide in the operator's cab can be used to fill the space under the housing, surrounding the engine quickly with an inert atmosphere.

In discussing safety problems with officials in England, it was learned that 7 fires have occurred on diesel locomotives in 5 years in that country. Fortunately, the fires so far have been confined to the locomotives. One cause of these fires was found to be slipping of the V-belts used to drive auxiliaries such as fans and pumps on the locomotives. The suggested remedy was to use a positive drive by chain or gears, or else use belts made of flame-resistant material. Another cause of fires has been high temperatures reached on surfaces of exhaust-gas conditioners. Oil and coal dust collecting between the locomotive frame and conditioner have caught fire. Tests were to be run to determine whether water jackets or water-spray injection into the exhaust would reduce the temperature of conditioners. It was stated that carbon dioxide fire extinguishers fixed in the locomotive are not

mandatory in England. It was also stated that the British standard for diesel locomotives eventually would closely resemble the requirements of the Federal Bureau of Mines as set forth in Schedule 22.[3] Plans are being drawn for a new test rig with which a complete locomotive can be tested under load.

Underground Photography

During the visit to the laboratories of the Ministry of Fuel and Power at Sheffield, England, it was learned that photographs of underground conditions are used to a considerable extent in reports on mine accidents and disasters as well as for educational purposes. Photographs of conditions found in a mine following an explosion or fire prove to be invaluable in efforts to determine causes as well as to devise measures to prevent similar accidents in the future. A copy of Research Report 53[4] was obtained. This publication describes methods employed and equipment used in making photographs in gassy coal mines. Although the publication is based on photography with approved self-contained portable lamps for illumination, explosion-proof lighting fixtures have since been developed, together with arrangements for connection to power circuits in the mine. The author was given photographs of this equipment.

CONCLUSION

In the conference and in the visits to the various mining experiment stations, the desire to exchange information of benefit toward improving health and safety conditions underground was plainly evident. Specialists in different types of research offered ideas and recommendations freely.

Although much progress has been made, research will continue at the different experiment stations, and there will be further need to report on progress made. Opportunity to do so will be afforded at the next international conference. The proposal already has been made that Belgium and The Netherlands serve as hosts, with sessions divided between the two countries, during the summer of 1956.

3/ Bureau of Mines, Procedure for Testing Diesel Mine Locomotives for Permissibility and Recommendations on the Use of Diesel Locomotives Underground: Schedule 22, 1944, 31 pp.

4/ Grice, C. S. W., and Russell, G. A., Still Photography in Coal Mines: Safety in Mines Research Establishment Research Rept. 53, 1952, 22 pp.

BIBLIOGRAPHY

The papers listed in this bibliography were presented at the Eighth Biennial Conference of Directors of Safety in Mines Research, July 1954, Derne, Germany. The papers are listed by conference number.

1. GRIMSHAW, H. C., and SHEPHERD, W. C. F. New Testing Procedure for Eq.S and Sheathed Explosives. Safety in Mines Research Establishment Research Rept. 98, England, 1954, 14 pp.

2. HARTMANN, IRVING, NAGY, JOHN, and CHRISTOFEL, F. P. Incombustible Required on Floor and on Rib-Roof Surfaces of Coal Mines to Prevent Propagation of Explosions. Bureau of Mines, United States Department of the Interior, Rept. of Investigations 5053, 1954, 7 pp.

3. HARTMANN, IRVING, JACOBSEN, MURRAY, and WILLIAMS, R. P. Laboratory Explosibility Study of American Coals. Bureau of Mines, United States Department of the Interior, Rept. of Investigations 5052, 1954, 8 pp.

4. LINACRE, E. T. The Salt-Crust Method of Roadway Treatment. Safety in Mines Research Establishment Research Rept. 94, England, 1954, 16 pp.

5. TITMAN, H., and WYNN, A. H. A. The Ignition of Explosive Gas Mixtures by Friction. Safety in Mines Research Establishment Research Rept. 95, England, 1954, 22 pp.

6. EISNER, H. S., and SMITH, P. B. Convection Effects from Underground Fires: The Backing of Smoke Against the Ventilation. Safety in Mines Research Establishment Research Rept. 96, England, 1954, 12 pp.

7. HANCOCK, J., and TAYLOR, W. Pulsed Infusion Shotfiring. Safety in Mines Research Establishment Research Rept. 97, England, 1954, 21 pp.

8. CURZON, G. E., and Eisner, H. S. The Diffusion of a Vapor Cloud in a Ventilated Roadway. Safety in Mines Research Establishment Research Rept. 99, England, 1954, 14 pp.

9. TAYLOR, W., and HANCOCK, J. Progress in Short Delay Shotfiring in Coal Mines. Imperial Chemical Industries, Ltd., England, 1954, 13 pp.

10. GLEIM, E. J. Portable Methane-Detecting Appliances Approved Under United States Bureau of Mines Standard. Bureau of Mines, United States Department of the Interior, Rept. of Investigations 5056, 1954, 6 pp.

11. _____. United States Bureau of Mines Standard for Inspection and Test of Explosion-Proof Enclosures for Mining Equipment. Bureau of Mines, United States Department of the Interior, Rept. of Investigations 5057, 1954, 7 pp.

12. GRANT, R. L., and MASON, C. M. The Mechanism of Ignition of Firedamp by Explosives. Bureau of Mines, United States Department of the Interior, Rept. of Investigations 5049, 1954, 8 pp.

13. GRANT, R. L., MASON, C. M., and DAMON, G. H. A New Method of Measurement of the Incendivity of Explosives to Firedamp. Bureau of Mines, United States Department of the Interior, Rept. of Investigations 5050, 1954, 4 pp.

14. HANNA, N. E., TIFFANY, J. E., and DAMON, G. H. Factors Affecting the Incendivity of Permissible Explosives. Bureau of Mines, United States Department of the Interior, Rept. of Investigations 5051, 1954, 11 pp.

15. HARTMANN, IRVING, NAGY, JOHN, and RAUSCHENBERGER, J. K. Lessons From Intensive Dust Sampling of a Coal Mine. Bureau of Mines, United States Department of the Interior, Rept. of Investigations 5054, 1954, 12 pp.

16. LOISON, R., and GILTAIRE, M. Ignition of Firedamp by Compressed-Air Blasts. Centre d'Etudes et Recherches des Charbonnages de France, France, 1954, 14 pp. (in English).

17. SARTORIUS, R. A Contribution to the Study of the Deflagration of Mining Explosives. Centre d'Etudes et Recherches des Charbonnages de France, France, 1954, 19 pp. (in English).

18. SARTORIUS, R., and THOUZEAU, G. The Interdependence of Successive Results in Shots With Explosives in the Testing Gallery: The Influence of Atmospheric Moisture. Centre d'Etudes et Recherches des Charbonnages de France, France, 1954, 25 pp. (in English).

19. WEHNER, E. /Technical Explosion Investigations of Industrial Dusts./ Berggewerkschaftliche Versuchsstrecke, Dortmund-Derne, Germany, 1954.

20. MORSBACH, W. /The Explosion Danger of Bituminous Coal Dust./ Berggewerkschaftliche Versuchsstrecke, Dortmund-Derne, Germany, 1954.

21. SCHULTZE-RHONHOF, H. The Development of Shotfiring in Germany Since the First Conference at Buxton. Berggewerkschaftliche Versuchsstrecke, Dortmund-Derne, Germany, 1954, 13 pp. (in English).

22. MAAS, W. Temporary Distortion of Flameproof Casings for Electrical Equipment. Staatmijnen, Limburg, The Netherlands, 1954, 19 pp. (in English).

23. MAAS, W. Memorandum on the Detection of Firedamp in Mines. Staatsmijnen, Limburg, The Netherlands, 1954, 4 pp. (in English).

24. DE BRAAF, W., and MAAS, W. /Measures for Preventing and Fighting Belt-Conveyor Fires./ Staatsmijnen, Limburg, The Netherlands, 1954.

25. KLINGER, K. /Large-Scale Mine Fire Experiments to Test Methods of Arresting Open Roadway Fires./ Versuchsgrube, Dortmund, Germany, 1954.

26. LOISON, R., and THOUZEAU, G. Risk of Ignition of Firedamp by Shotfiring in a Mortar With a Stemming Plate. Centre d'Etudes et Recherches des Charbonnages de France, France, 1954, 13 pp. (in English).

27. VANPEE, M. /The Mechanism of Ignition of Methane-Oxygen Mixtures./ Institut National des Mines Belgique, Belgium, 1954.

28. MASKOW, H. Ignition by Ejection of Particles. Berggewerkschaftliche Versuchsstrecke, Dortmund-Derne, Germany, 1954, 7 pp. (in English).

29. AHRENS, H. /Safe Explosives of High Power./ Berggewerkschaftliche Versuchsstrecke, Dortmund-Derne, Germany, 1954.

30. _____. Observations on the Behavior of Salt-Type Constituents of Safety Explosives. Berggewerkschaftliche Versuchsstrecke, Dortmund-Derne, Germany, 1954, 20 pp. (in English).

31. SCHULTZE-RHONHOF, H. /Wet Processes for Combating Firedamp and Coal-Dust Explosions./ Berggewerkschaftliche Versuchsstrecke, Dortmund-Derne, Germany, 1954.

32. FRIPIAT, J. Investigations Into the Safety of Electrical Shotfiring. Institut National des Mines‹Belgique, Belgium, 1954, 12 pp. (in English).

33. WINTER, KARL. /Portable Apparatus for the Underground Determination of Firedamp in Bituminous Coal Mines./ Westfalische Berggewerkschaftskasse, Germany, 1954.

34. BREDENBRUCH, E. /Origin and Prevention of Mine Fires./ Steinkohlenbergbauverein, Germany, 1954.

35. VON HOFF, C. /Recent Developments in Breathing Apparatus in the German Mining Industry./ Steinkohlenbergbauverein, Germany, 1954.

36. FISCHER, KARL. /The Action of Stone Dust on Coal-Dust Explosions./ Versuchsgrube Tremonia, Dortmund, Germany, 1954.

37. LOISON, R., CHAINEAUX, L., and DELCLAUX, J. Study of Some Safety Problems in Firedamp Drainage. Dentre d'Etudes et Recherches des Charbonnages de France, France, 1954, 19 pp. (in English).

38. LOISON, R. /Ignition of Coal Dust by Shotfiring./ Centre d'Etudes et Recherches des Charbonnages de France, France, 1954.

39. LINGENBERG, H. /Special Analytical Methods for the Determination of Gases and Suspended Matter in Detonation Products of Shotfiring./ Berggewerkschaftliche Versuchsstrecke, Dortmund-Derne, 1954.

40. CYBULSKI, W. /Further Experiments on the Safety of Explosives in the Presence of Coal Dust./ Glownego Instytutu Gornictwa, Kopalnia Doswiadczalna Barbara, Poland, 1954.

41. _____. /Experiments to Determine the Explosion Limits of Coal Dust./ Glownego Instytutu Gornictwa, Kopalnia Doswiadczalna Barbara, Poland, 1954.

42. HELLMUND, F. /Installations at the Berggewerkschaftliche Versuchsstrecke for the Flameproof Testing of Electrical Plant When Under Load./ Berggewerkschaftliche Versuchsstrecke, Dortmund-Derne, Germany, 1954.

43. WEHNER, E. Electrical Intrinsic Safety in Shotfiring. Berggewerkschaftliche Versuchsstrecke, Dortmund-Derne, Germany, 1954, 9 pp. (in English).

44. FRIPIAT, J. Recent Research on Safety Explosives. Institut National des Mines Belgique, Belgium, 1954, 14 pp. (in English).

45. HULSBERG, FR. /The Type of Protection Called "Increased Safety."/ Berggewerkschaftliche Versuchsstrecke, Dortmund-Derne, Germany, 1954.

46. CYBULSKI, W. /Research on Problems Relating to the Efficacy of Stone-Dust Barriers, Especially in the Vicinity of a Gassy Zone./ Glownego Instytutu Gornictwa, Kopalnia Doswiadczalna Barbara, Poland, 1954.